

■ PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

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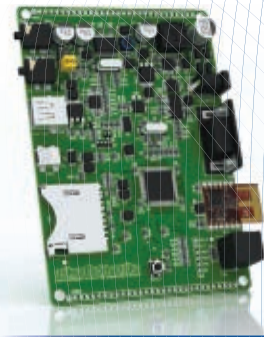
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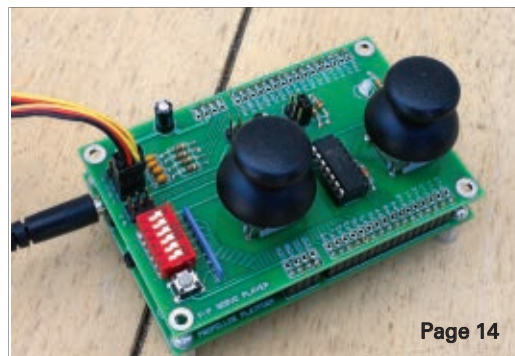
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Projects & Features

30 Make the PLL Frequency Synthesizer with PIC Control

This project describes how to build a frequency synthesizer — a device which generates a stable waveform at a user-selected frequency. Frequency synthesizers are handy test instruments for digital circuits, and can also be used for audio signal generators or radio frequency mixing applications. This project is easy to build, easy to use, and a great way to learn more about how phase-locked loops work.

■ By Dan Gravatt

36 Flower Power

You too can power a device from a set of potted plants! However, in this case, the cells of the battery draw their energy directly from the plants, rather than from an electrochemical process.

■ By Carlos Cossio

42 Build a Low Voltage Insulation Tester

Wire that we use on our projects is replaced when the insulation starts to look bad. What about hidden wire that had been installed in a large building more than 20 years ago? This easy modification allows a low tech analog ohmmeter to detect insulation faults that a high tech digital ohmmeter fails to find.

■ By Douglas Krantz

50 The Projects of Prototype This!

Joe Grand takes a closer look at the electronic aspects of his different builds from the popular Discovery Channel show Prototype This! This month, go deep with a virtual sea adventure.

■ With Joe Grand

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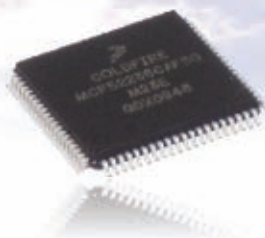
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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

When Water and Electronics Mix

This past May, the Cumberland River crested 12 feet above flood stage, resulting in flash flooding of Nashville. In addition to the lost lives and thousands left homeless, a major instrument storage facility was completely flooded. Tens of millions of dollars worth of guitars, amplifiers, and sound equipment were submerged for days. Many of the acoustic instruments will never grace the stage again because the wood was split or otherwise ruined. The ultimate fate of the electronics is another matter, but odds are, much can be saved. The point of this editorial is that if you know what you're doing, you can often resuscitate electronics that have been submerged. And, sooner or later, someone is going to bring you a piece of electronic equipment that was either submerged or left out in the rain. So, how will you handle it? First, there are no guarantees — especially if the device was powered up when it went for a dive. And, in general, the older the device, the better.

The worst case I've had was an IBM ThinkPad that had a bowl of cheerios and milk spilled into the keyboard. I've also saved a switching power supply and 2m transceiver that were submerged in salt water. I lost an inexpensive MP3 player to

the rain, despite valiant attempts to revive it. It is possible to save an MP3 player or cell phone that's been used in the rain or dunked in a pool by mistake. However, you really want to get at the components and circuit board, and that's difficult with devices that have no obvious entry points.

The goal is to remove any water and, more importantly, any residue that was carried by the water or caused by water interacting with the electronics. So, if your AM radio took a dip in the sea, you've got to get rid of the salt as well as the water. Clean, fresh water is less problematic, but ponds, lakes, and toilets tend to be filled with something other than clean and fresh liquid.

So, my solution for submerged electronics goes something like this: First, remove all sources of power, including batteries. This includes the thin lithium cells used in laptops, camcorders, and other handheld devices, and the 9V batteries used as backup for clock radios. Most laptops have at least two batteries. Next, disassemble the unit if you can. Remove speaker cones and anything else that would be damaged by additional contact with water. Next, spray the components and board liberally with distilled water. Use a hand-pump sprayer on the highest setting — you want a

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powerful stream of water, not a fine mist. If the unit was immersed in salt water and it contains a power transformer, then dunk the part of the board containing the transformer in distilled water. The idea is to dissolve any salt deposits that may be forming between the windings. Follow up with a rubbing alcohol chaser to displace the water. Now, examine the board for deposits between the traces. If you spot any, remove them with Q-tips and either rubbing alcohol or an alcohol-based cleaner. Dry the device with paper towels and place it in front of a fan in a warm (but not hot) room. Don't use a heat gun or stick the board in your oven.

Physically check the device after four or five days. It should be bone dry. If it isn't, then put it away and check it in another few days. When you're satisfied that there's no water in the device, drop in the batteries and power it up. Hopefully, all will be in working order. If not, well, most warranties don't cover water damage anyway. At least you've learned something from the teardown. If you have any tales of your own water rescue attempts, or you've developed a killer process for saving dunked electronics, please consider sharing them with our readers. **NV**

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■ BY JEFF ECKERT

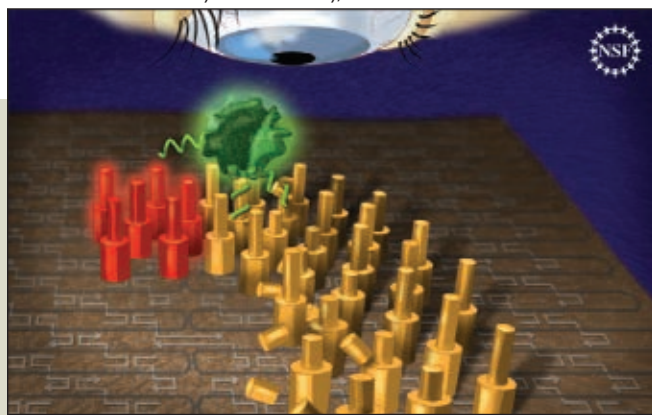
ADVANCED TECHNOLOGY

MOLECULAR BOT WALKS AND DECIDES

You won't find any of these things welding car bodies or mixing cocktails, but ongoing research is aimed at creating molecular-scale automatons that could do repair work on human cells or perform assembly functions on a nanotech scale. One concept involves reprogramming DNA molecules to perform specific tasks. The question — as posed by Mitra Basu, a program director at the National Science Foundation (www.nsf.gov) — is "Can you instruct a biomolecule to move and function in a certain way? Researchers at the interface of computer science, chemistry, biology, and engineering are attempting to do just that."

As it turns out, investigators at Columbia, Arizona State, Michigan, and Caltech (www.columbia.edu, www.asu.edu, www.umich.edu, and www.caltech.edu) have created and programmed robotic DNA molecules that briefly walk on spidery "legs" and move through a special two-dimensional landscape. The little bots have proven to be capable of rudimentary robotic actions consisting of starting motion, walking, turning, and stopping. As shown in the artist's rendition, as a bot (green) walks along the substrate, it changes the little

Photo courtesy of Zina Deretsky, National Science Foundation.



■ Molecular robot moves along a special substrate, chopping off tiny elongations.

vertical nubbins by breaking off their thin parts. If it reaches a spot where a previous traveler has already chopped one off, it moves along faster. When it reaches the end of the track (red), it is captured and comes to a halt. Note that we're not talking about long distances or rapid movement here; the 4 nm walkers plod along at 100 to 200 nm per hour by taking about 100 steps. Previous versions conked out after only about three steps, so this is a big improvement. According to Basu, "This work one day may lead to effective control of chronic diseases such as diabetes or cancer." ▲

LASER GENERATES BURSTS OF NOTHING

Researchers at the National Institute of Standards and Technology (NIST; www.nist.gov) and JILA (jila.colorado.edu) recently reported the development of a new kind of semiconductor laser that "excels at not producing light." The description seems a little contrived, as I'm pretty sure my shoe is even better at not producing light. But it is interesting, as the "dark pulse" laser could conceivably be useful in measurements and communications. Because dark pulses — unlike their bright counterparts — generally propagate without distortion, they might turn out to be useful in signal processing applications. "Dark pulses might be used like a camera shutter for a continuous light beam in optical networks."

Basically, you inject electrical currents into a few million 10 nm quantum dots (qdots), causing them to emit light at

■ Colorized trace of pulses from the "dark pulse" laser. Light output nearly shuts down about every 2.5 ns.

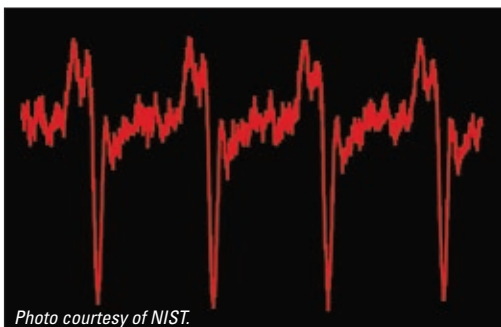


Photo courtesy of NIST.

the same frequency. Thereafter, the "qdots recover energy from within rapidly (in about 1 ps) but more slowly (in about 200 ps) from energy inputs originating outside the qdots in the laser cavity. This creates a progression of overall energy gains gradually giving way to overall energy losses. Eventually, the laser reaches a steady state of repeated brief intensity dips — a drop of about 70 percent — from the continuous light background." The new technology is said to be the first to generate dark pulses from the laser cavity, without any subsequent electrical or optical pulse shaping. However, whether dark pulse communication systems will ever become a reality is debatable. Purdue laser researcher Andy Weiner (having reviewed the concept) was quoted as saying, "Current practice and directions in lightwave communications are such that I don't think it likely there will be practical interest in dark pulse lightwave communication systems." Time will tell. ▲

COMPUTERS AND NETWORKING

UPGRADE YOUR SOUND

Some of us old fossils fondly remember the old Altec Lansing Voice of the Theatre speakers, first introduced in 1945. They were the only speaker series to be approved by the Research Council of the Academy of Motion Picture Arts and Science which made them the standard for motion picture playback for decades, not to mention a dream PA pair for rock bands everywhere. Oddly enough, these amazing boxes were reintroduced a few years ago as the Legacy A7 model. At \$5,800 each, though, we may as well stop talking about them. So we will.

However, if you want to upgrade your PC's audio output with a system from the legendary company, you can get the equipment and status for a mere \$79.95 in the form of the Octane Plus 2.1 system. It can also be hooked up to CD, DVD, and MP3 players, and it's specifically tuned for music, movies, and gaming with a subwoofer, a pair of down-firing 3 inch mid-range speakers, and two 1 inch micro drivers. The down-firing concept involves blasting the sound waves downward onto a hard surface from which they are reflected around the room. This is said to provide balanced sound from a smaller footprint. The bass comes from a 6.5 inch woofer. Separate bass and treble controls allow you to fine-tune the sound. As of this writing, you can get a pair directly from www.alteclansing.com or order from Amazon. ▲



■ Altec's Octane Plus 2.1 speaker system.

FIRST 3D NOTEBOOK INTRODUCED

As previously noted here, the hot marketing craze in the world of electronics is 3D, and Toshiba (www.toshiba.com) has jumped in with what it says is the industry's first notebook PC to support the Blu-ray 3D format. At press time, the Dynabook TX/98MBL was still available only in Japan, but it could be in stores by the time you read this. The machine uses WinDVD® BD software to play back content in the Blu-ray 3D™ format and NVIDIA® 3D Vision™ software and hardware to deliver the 3D experience. It uses the same active shutter technology as movie theaters in which the active shutter LCD glasses lighten and darken at the same 120 Hz rate as the LCD for an effective refresh rate of 60 Hz. Each of your eyes sees a slightly different image, so the overall picture is stereoscopic. The machine comes with a pair of wireless shutter glasses and incorporates Harman/Kardon speakers and Dolby audio. Other features include an Intel Core i7-740QM processor, a 15.6 inch display, a 640 GB drive, and 4 GB of RAM. No official list price was announced by Toshiba, but word on the street is that it will drain your account by about \$2,750. ▲

INDUSTRY AND THE PROFESSION

IBM TWEAKS MICROSOFT

There was no official announcement, but the grapevine has it that IBM has asked all of its 400,000 employees to set Mozilla's (www.mozilla.org) Firefox as their default Web browser. The switch is not mandatory, but all new computers in IBM installations will come with it preloaded, so the policy is expected to benefit Mozilla largely at the expense of Microsoft's Internet Explorer. Firefox presently has a bit less than 25% of the market, compared to about 60% for IE. Other browsers remain far behind, but it's a little early to gauge the impact of Google's Chrome. The move probably shouldn't be viewed as a direct swipe at Microsoft. Although, among the cited reasons for IBM's decision are that Firefox is open source, standards compliant, secure, and extensible. ▲

NIST OFFERS FELLOWSHIPS

In February, the National Institute of Standards and Technology (NIST; www.nist.gov) awarded \$19.5 million to the University of Maryland and the University of Colorado to administer measurement science and engineering fellowships for graduate, post-doctoral, and senior researchers. Applications are being accepted, so if you are interested in a position at either the NIST campus in Gaithersburg, MD, or the Hollings Marine Lab in Charleston, SC, it's time to belly up to the trough. Funded by the American Recovery and Reinvestment Act, positions are available for "highly qualified US citizens and non-citizens from academic, industrial, and other organizations." For information on the University of Maryland administered portion of the program, visit www.nistfellows.umd.edu; for information on the one managed by the University of Colorado, go to www.colorado.edu/nistfellows. The program will continue in 2011 and 2012, and will include undergraduates. ▲

CIRCUITS AND DEVICES

XLR-TO-USB MIC CONVERTER

If you use your computer for serious audio applications (digital recording and mixing, podcasting, etc.), you may have made the sad discovery that your collection of fine old studio microphones have an impedance mismatch with the audio-in port on the computer and just don't work. You may also have discovered that good USB mics aren't cheap. Well, never fear, because the folks at Blue Microphones (www.bluemic.com) have created the Icicle — a USB converter and mic preamp combo that allows you to plug your

■ The Icicle converter from Blue Microphones.

cherished Shure 55S, EV 726, or any other XLR-connected mic into your computer. It features a studio-quality preamp, 48V phantom power, a balanced low noise front end, analog gain control, and driverless operation. The Icicle works with both dynamic and condenser microphones, and with Mac or PC. You just need Windows Vista or XP or OSX and a paltry 64 MB of spare RAM. Best of all, you can pick one up for about \$40 if you shop around. ▲



THE RETURN OF THE NIXIE

Most of us remember nixie tubes — the original cold-cathode digital displays widely used in the old days in multimeters, frequency counters, calculators, and so on. Now you can amaze your friends with a retro nixie clock, and you don't even have to build it yourself. The device is offered by LNS Technologies through distributors and their www.techkits.com website. What you get is a fully assembled clock featuring side-view Z573M/Z574M tubes, 13 mm high, and factory coated with a red contrast filter for sharpness enhancement. A DC/DC converter generates the voltage needed to drive the tubes, and the clock is encased in a clear Plexiglas cabinet. Power is drawn from a standard 12V wall adaptor. The colon in the center blinks every second, and the unit even features a battery backup. The only snag is the \$99 price tag, but nostalgia doesn't come cheap. Plus, you can tell your non-tech friends that it's a spectacular new technology. ▲



■ The nifty nixie clock from LNS Technologies.

POT+ SWITCH OFFERS CONTROL OPTIONS

Electro-Mech Components (www.electromechcomp.com) is offering a nifty potentiometer/switch assembly that offers dual control options. Aimed at applications such as industrial/avionics displays, audio controls, instrument panel controls, and other high density panels, the SPDT SW44687 is an all-in-one unit that offers both rotary and push-on functionality along with a 10K resistance pot module. This allows users of the equipment to preset the pot level and open the circuit by pressing the button. The unit weighs less than an ounce, measures less than 3/4 inches square, and requires less than an inch of space behind the display panel. Interconnection is via wire leads, PC pins, or solder lug terminals. The SW44687 is rated at 30 VDC or 120 VAC, and is rated for 100,000 minimum actuations. An edge-lit button is optional. ▲

■ Electro-Mech's SW44687 offers dual control options.



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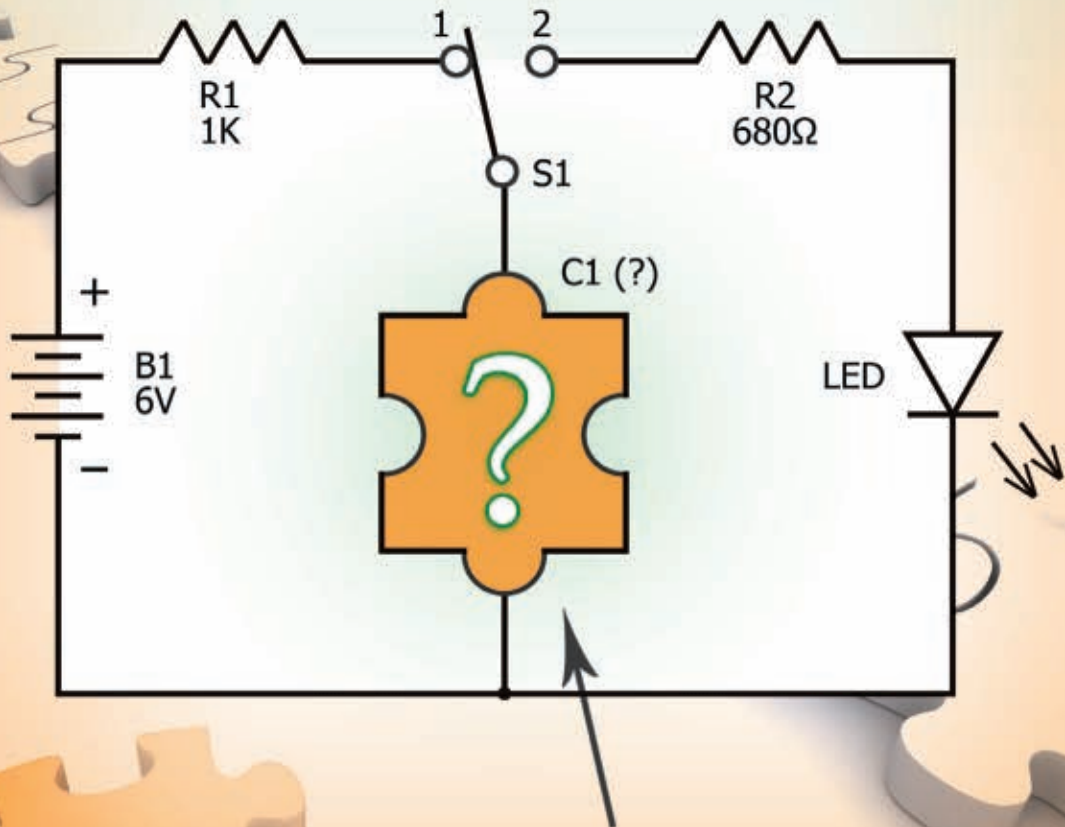
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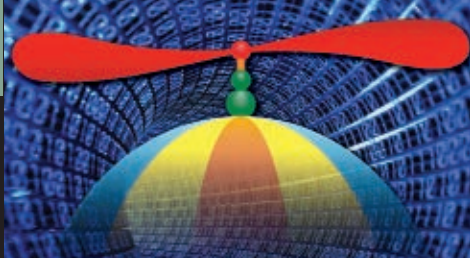
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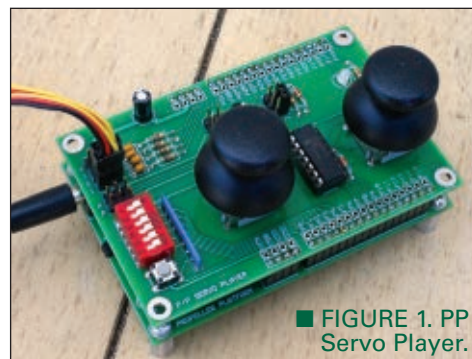
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■ BY JON WILLIAMS

THE JOY OF JOYSTICKS

I think it's fair to say that the joystick may be the first user input device connected to a computer that took us beyond the keyboard – games are far more fun with a stick in our hand than hunting for keys, right? The first joysticks, of course, were simply made up of switches pressed by a plate connected to the stick. Then came analog joysticks which were built up with two potentiometers mechanically linked at a 90-degree angle; one pot for each axis. The original PC joysticks were easy to connect to microcontrollers without hacking. With the proliferation of USB ports, though, analog joysticks changed their interface and are no longer microcontroller-friendly. Darn ...



■ FIGURE 1. PP Servo Player.

GAME ON!

If you've played on any video game console in the last 10 years, you've no doubt had the opportunity to place your thumbs on the controller's mini joysticks and go crazy with your friends. Until recently, those mini joysticks with their cute, mushroom-shaped caps weren't very easy to come by and (when you could find them) they were pricey – a few years ago, I paid about \$10 each.

Well, that's not the case anymore. Parallax offers a version (#27800) that we can plug into solderless breadboards, and Nick over at Gadget Gangster is offering them as raw parts that we can build into projects. So, the hardware this month is a Propeller Platform module that holds two of those mini joysticks, an ADC to read them, and some other bits that we can use in a variety of projects. **Figure 1** shows my completed prototype.

USING THE MCP3204

The mini joysticks are, in fact, two 10K potentiometers that are mechanically linked together such that one changes with X-axis movement; the other changes with Y-axis movement. With two joysticks, we'll need a four-channel ADC. We could use an ADC0834 but the MCP3204 seems to be popular among Propeller users so I thought I'd give it a whirl.

Figure 2 shows the connections between the joysticks and the MCP3204 – a four-channel, 12-bit ADC. The MCP3204 has four pins that form the communication buss to the host microcontroller, but the addition of a 2.2K

resistor allows us to cut that down to three. The resistor protects the Propeller pin from a short circuit when DOUT is an output, the I/O pin is an output, and the two are in opposite states (one high, one low).

The process of reading a channel value from the MCP3204 requires these steps:

1. Take the /CS line low.
2. Output a five-bit configuration word.
3. Read 13 bits from the ADC (null plus 12 bits).
4. Return the /CS line high to deselect.

The MCP3204 will handle very high speed transactions and we could write a driver in assembly but, really, there's no need for most applications. I've created a simple object written completely in Spin that will handle reading any of the channels in the two modes that are supported (single-ended and differential).

The MCP3204 object has methods to set up the I/O pins used by the circuit and two variants that will read the value of a channel. The **init()** method takes care of the I/O pins and places the '3204 in the deselected state:

```
pub init(cspin, clkpin, diopin)

  cs := cspin
  outa[cs] := 1
  dira[cs] := 1

  clk := clkpin
  outa[clk] := 0
  dira[clk] := 1

  dio := diopin
```

As you can see, we pass the chip select pin, the clock pin, and the data I/O pin to the *init()* method. The /CS pin is set to output and high to deselect the '3204 while the clock pin is set to output and low; the data I/O pin is left in input mode until we need it.

Astute readers (that would be you!) will ask, "Why do we need to pass pin numbers when they won't change in a program? Can't we just set them as constants?" We could, but it's a bad idea for reusable objects like this. If we used constants for the pin numbers, we'd be forced to either: 1) always use the same pin numbers in every design (impractical); or 2) keep multiple copies of the object with different pin numbers which is also impractical when it comes to maintenance and upgrades. So, the lesson here is this: When designing a Propeller object, keep it concise yet flexible enough to be re-used in any of your designs. This will make your life simpler, and those downloading your code from the Object Exchange (ObEx) will thank you.

There are two variations of read methods and, in fact, one calls the other. The reason for two methods is to accommodate different programming styles. The first variation expects the channel number (0 to 3) and the mode (1 for single-ended; 0 for differential):

```
pub read(ch, m) | mux
    mux := %1_0000 | ((m & 1) << 3) {
        } | (ch & %11)
    return readx(mux)
```

The channel and mode settings are used to create a five-bit configuration word with masking and bit shifting; this value will be passed to the *readx()* method that actually does the heavy lifting:

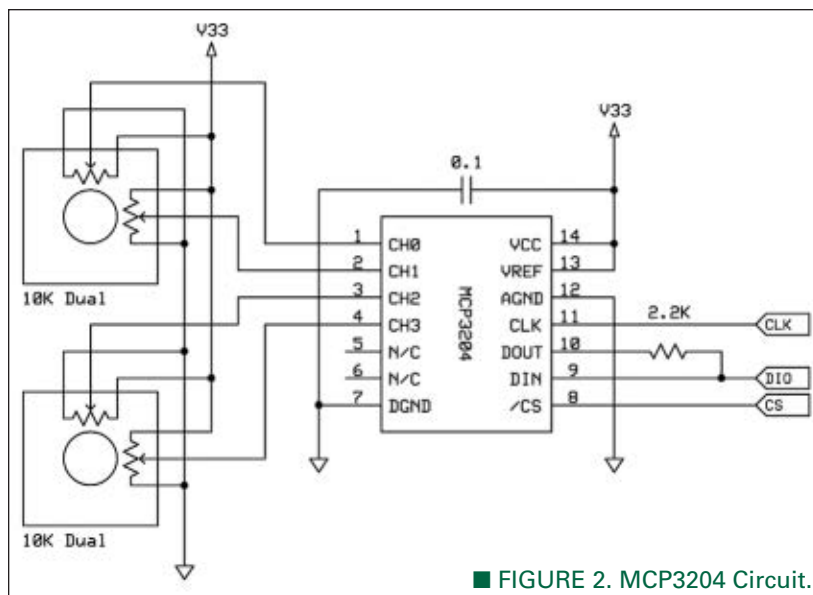
```
pub readx(mux) | level
    outa[cs] := 0
    dira[dio] := 1

    mux <= constant(32-5)
    repeat 5
        outa[dio] := (mux <= 1) & 1
        outa[clk] := 1
        outa[clk] := 0

    dira[dio] := 0
    level := 0
    repeat 13
        outa[clk] := 1
        outa[clk] := 0
        level := (level << 1) | ina[dio]

    outa[cs] := 1
    return (level & $FFF)
```

If this code looks a little bit familiar, well, it should. It's really a combination of code that simulates the PBASIC **SHIFTOUT** and **SHIFIN** instructions; we used code identical in the latter portion when reading the 74x165 shift-register on the encoder board (*Nuts & Volts*, May '10). Just a note on my method of naming convention:



■ FIGURE 2. MCP3204 Circuit.

When I have two methods that are similar and one is a simplified interface into the other, the method that really does the work tends to get appended with "x" (for explicit).

We start by taking the /CS line low to activate the '3204. Remember that the *init()* method made this pin an output, so all we have to do is set the level by writing to the *outa[]* register. The next step is to put the DIO line into output mode so that we can write the configuration word to the '3204.

The configuration word is shifted out MSB (Most Significant Bit) first. The cleanest way to do this in Spin is to move the MSB of the configuration word into bit 31; we do this with a right shift (of 27 bits). Next, we drop into a **repeat** loop that starts by rotating bit 31 into bit 0; bit 0 is then moved to the DIO pin, and the clock pulsed high then low to latch the bit into the '3204.

To receive the channel value from the ADC, we switch the DIO line to input mode, clear the workspace variable, and then drop into a **repeat** loop that shifts the bits in. As you can see, the loop runs 13 times; the reason for this is that the '3204 outputs a null bit before the first bit (MSB) of the channel reading.

To shift the ADC, bits in the clock line are pulsed high, then low; we'll sample the line after the clock pulse (MSBPOST). The bits arrive MSB first so the work value is shifted left before the DIO line is sampled and copied into bit 0.

Finally, the /CS line is taken back high to deselect the ADC, and we can return the value to the calling program. Note that while this code is set up for the '3204, a very simple change will allow it to work with the MCP3208 as well; both devices use a five-bit configuration word.

Okay then, let's put it to use. I'm a very big believer in creating hardware test programs before moving on to the actual application (more on this later), and part of the test program for the board I made will read and display the analog joystick inputs. **Figure 3** shows the output of this code in PST.

Do you see a problem? These readings are with the joysticks at neutral, and in a perfect world all would read

2048 as this is the half-way point for a 12-bit ADC. One of my desires is to control servos with the joysticks, so a little extra effort will be required to make this work cleanly.

The first thing to do is nullify the neutral position values; the **autocal()** method does this:

```
pub autocal | idx, raw
  repeat idx from 0 to 3
    raw := adc.read(idx, adc#SE) >> 4
    ofs[idx] := JOY_CNTR - raw
```

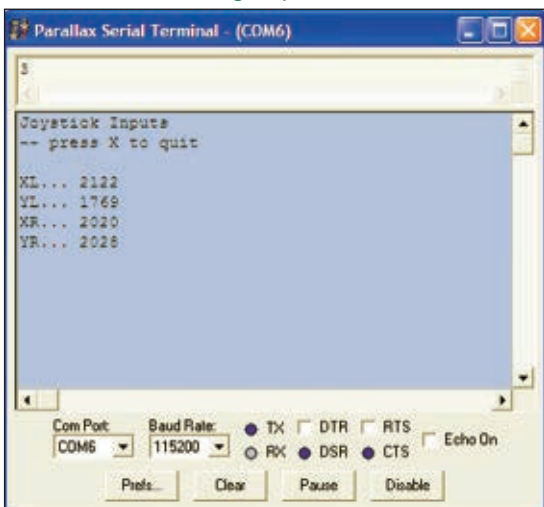
There are actually two things happening here: the channel is read (in single-ended mode) and then shifted right by four bits to reduce the ADC resolution down to eight bits; the pots we're using are not precision units and 12 bits is excessive. By reducing the resolution, we can nearly eliminate the LSB "bouncing" of the input readings. The second step is to save the offset from expected center (128 for eight bits) in an array that can be applied to future readings.

So, let's say that we want to control four servos with the headers on the board: The final step would be to convert the joystick channel reading to the range required by the servo driver. This value will usually be expressed in microseconds, and 1000 to 2000 is the standard range. The **joy2servo()** method takes an eight-bit joystick reading and, using algebra, converts it to a standard servo position value:

```
pub joy2servo(jpos) | delta, spos
  jpos := JOY_MIN #> jpos <# JOY_MAX
  delta := (jpos - JOY_MIN) * 1000 {
    } / (JOY_MAX - JOY_MIN)
  spos := ((SVO_MAX - SVO_MIN) {
    } * delta / 1000) + SVO_MIN
  return spos
```

The first step ensures that the input value in *jpos* is legal, that is, it fits within the eight-bit range we should expect from the joystick. With the variations in the pots, I decided to truncate the readings by 15 on each end, so

■ FIGURE 3. Reading Joysticks.



jpos will fall between 15 (JOY_MIN) and 240 (JOY_MAX).

The next step converts *jpos* to a percentage. For example, if the joystick is in the neutral position (*jpos* = 128), then *delta* will be 50%. Since we're dealing with integers, the percentage is multiplied by 1,000 to prevent rounding errors.

The final step translates the input *delta* to a servo position value, as defined by the minimum and maximum servo position constants. As you can see, the calculated position *delta* is applied to the span of the servo range and then divided by 1,000 to get to the value within the span; this is added to the minimum value for the range to get the proper servo position value. **Figure 4** shows the output from **jm_joystick_servo_demo.spin**. As you can see, the calibration has taken care of getting the neutral position where it needs to be, and the center value for a typical servo is properly calculated. The program includes a mini servo driver which allows us to control four servos from the joysticks.

PULSE POSITION MAGIC

A couple years ago, I was visiting my friend Dan at a Hollywood special effects shop, and he showed me a box of VEX transmitters that his company had purchased from All Electronics when the price was really low (about \$30 — and you can still find these units on eBay). Dan was gutting the joysticks from the transmitters for use in animatronics controls, but for many projects, there's no need to do this.

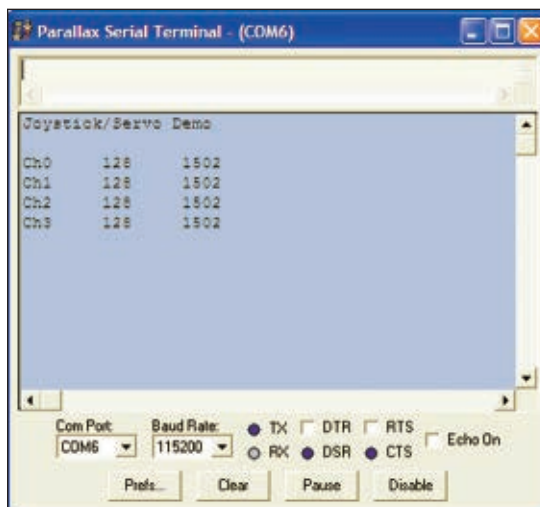
Most RC transmitters — including the one from VEX — have a trainer connection that emits a pulse stream that defines the position data of the joysticks and buttons.

Figure 5 shows the stream from the six-channel VEX transmitter when it's connected to a microcontroller. The actual output of the VEX is open-collector, so the input to the micro needs a pull-up.

In order to provide the greatest flexibility, I used the circuit shown in **Figure 6** on the project board. Two jumpers let me configure the three-pin PPM port; I can provide power to the device (e.g., a VEX receiver) and configure the input as pulled up or pulled down as required. The purpose of the 2.2K series resistor is to limit

the current into the Propeller I/O pin for those devices that provide a driven output (5V max).

The VEX stream begins with a nine millisecond sync pulse and is followed by six channel pulses. All of the pulses are separated by an idle period of about 390 microseconds. The value for a channel is



■ FIGURE 4. Joystick to Servo.

determined by measuring the period from one falling edge, through the idle period, to the next falling edge. In the past, I've measured pulses with the Propeller counters, but this time we'll need to measure the low and high portions of the signal, and we'll want to ensure that a shorted input or disconnected cable does not cause the values into the system to become corrupted.

The only way to measure the PPM pulse stream with precision is to use assembly code. I'll admit that it is a little involved, but really not too bad when broken down piece by piece. Let's jump in.

At the very top, we're going to start by writing a flag indicating there is no detected PPM stream, then we'll monitor the input for a valid sync pulse:

```
vexin      mov     dira, #0
           wrlong  NO, flagpntr

findsync   mov     pwidth, #0
           mov     timer, US_001
           waitpne pmask, pmask
           add     timer, cnt
:loop      waitcnt timer, US_001
           add     pwidth, #1
           test    pmask, ina      wz
           if_z    jmp     #:loop
           cmp     pwidth, SYNC   wc, wz
           if_b    jmp     #vexin
```

At **findsync**, the pulse width variable is cleared and a timer is set up for one microsecond delays with **waitcnt**. Then, we wait for the input to be low using **waitpne**. Note that this is the only place in the code where we will use a pin wait instruction; from this point forward, we will manually scan the input so that we can do it on a timed interval (one us).

Once a low on the input is detected, the timer is started and drops into a loop, incrementing the pulse width measurement every microsecond until the line goes back high. We scan the PPM input using the **test** instruction with a mask for the input pin (*pmask*) and the pin input's register (*ina*). The **test** instruction works exactly like the **and** instruction but it doesn't affect the variable in the destination field. The Z flag is updated with the state of the PPM input and as long as it remains true (Z = line is low), the code will loop and increment the pulse measurement variable. When the input goes high (during the inter-pulse idle period), the Z flag will be cleared and the code drops into a comparison to check the width of the pulse. If the pulse we just measured is not a valid sync pulse (for example, we started the code in the middle of an output stream), then the code

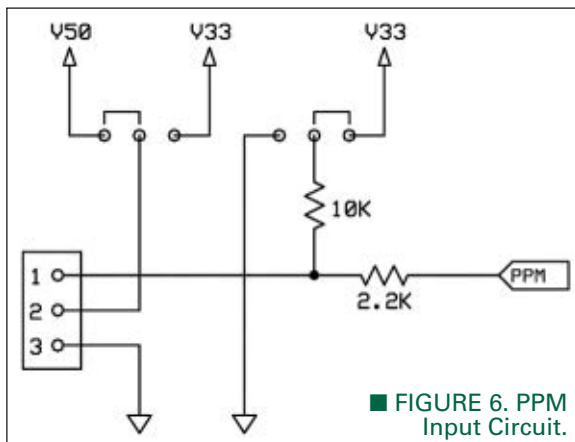


FIGURE 6. PPM Input Circuit.

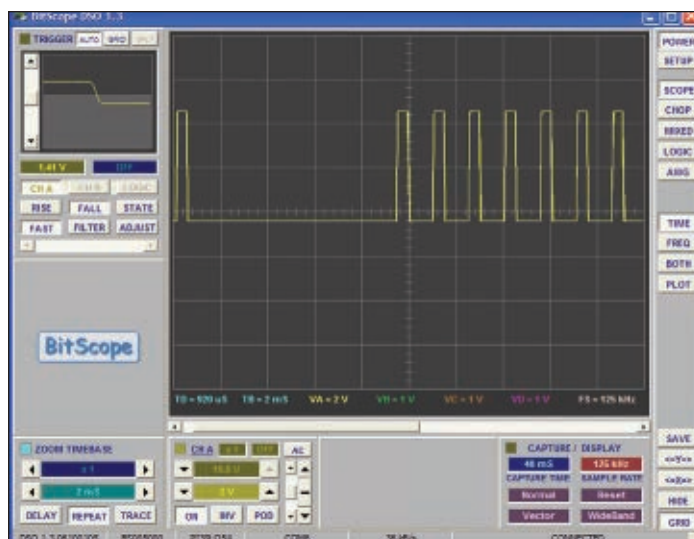


FIGURE 5. VEX PPM Stream.

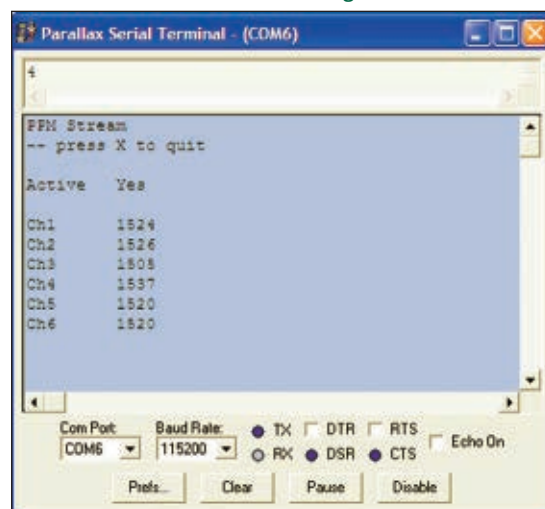
jumps back to the top and tries again.

The next section of code monitors and measures the idle period between the sync pulse and the first channel pulse. The reason we bother measuring is to prevent a disconnected device from locking the program (since we're waiting for a low-going leading edge for the channel measurement):

```
chwait     mov     pwidth, #0
           test    pmask, ina      wz
           if_z    jmp     #getch1
           waitcnt timer, US_001
           add     pwidth, #1
           cmp     pwidth, #425   wc, wz
           if_b    jmp     #chwait
           jmp     #vexin
```

As before, the pulse width variable is cleared and the code drops into a small loop that tests the state of the PPM line. When the line is idle, the Z flag will be cleared and we drop through the first jump into a one microsecond delay. The idle pulse width is incremented and a comparison is done to ensure that we haven't lost

FIGURE 7. Reading the PPM Stream.



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RX1-RX2 10K dual	Gadget Gangster	RKJXK122000D
SW1	DIP-6x	Mouser 611-BD06
SW2	6 mm NO	Mouser 653-B3F-1022
S-U1	14-pin DIP	Mouser 571-1-390261-3
U1	MCP3204	Mouser 579-MCP3204-CI/P
X1-X10	0.1 M-STRT	Mouser 517-6111TG *
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Parts Kit		Gadget Gangster

* The 517-6111TG is a 40-pin component; only three are required for the project (split as needed).

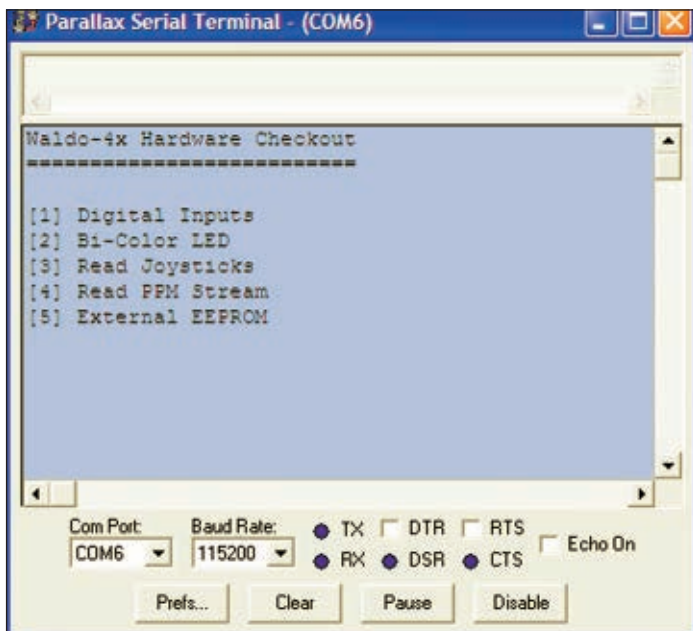
the signal. If the PPM signal is lost, the input will remain high and code is redirected back to the top of the program where we'll wait for reconnection and a valid sync pulse.

When things are working as they should, the PPM input will drop after about 390 microseconds — this is where we start the channel position measurement. This code looks — and is — very easy; it's actually just a call to a subroutine and a check on an error flag (stored in C) that can be set by that routine:

```
getch1    call    #getch
if_c      jmp     #vexin
          mov     chlus, pwidth
```

As you can see, this section calls a subroutine called

■ FIGURE 8. Test Menu.



getch which performs the actual channel measurement and will set the C flag if a measurement error is detected. After returning from the measurement routine, we check the C flag and if it's set, jump right back to the very top of the program where the PPM stream detection flag is set to NO (false). This flag can be used by our application to determine the presence or absence of the PPM stream and take some action based on that status. Assuming a good measurement, though, we save the channel timing in a holding register and then do the same operation for the rest of the channels.

The hard work is performed by the **getch** subroutine:

```
getch      mov     pwidth, #0
:looplo    waitcnt timer, US_001
          add     pwidth, #1
          cmp     pwidth, LO_MAX    wc, wz
          if_a    jmp     #badch
          test    pmask, ina        wz
          if_z    jmp     #:looplo

:loopphi   waitcnt timer, US_001
          add     pwidth, #1
          cmp     pwidth, CH_MAX    wc, wz
          if_a    jmp     #badch
          test    pmask, ina        wz
          if_nz   jmp     #:loopphi

goodch     cmp     pwidth, CH_MIN    wc, wz
          jmp     #getch_ret

badch      test    $, #1             wc
getch_ret  ret
```

Yeah, this does look a little bit hairy, but as you examine it closely, you'll find it's divided into two sections: the first to measure the low portion of the period; the second to measure the idle period which completes the channel timing.

Again, we start by clearing the timing measurement variable (*pwidth*) and then doing a one microsecond delay. The pulse timing is incremented and then compared to a constant that defines the longest valid low period. We do this so that a short on the PPM input can be detected. If this happens, the C flag gets set and we abort back to the calling code.

This usually won't happen, though, and we continue timing until the PPM line goes back high for the idle period. Now, we time this while waiting for the line to go back low (the start of the next channel); again, testing against an established limit. The test during the high period will detect a disconnection of the VEX device from the circuit. When we return to the calling section, the variable called *pwidth* will contain the channel value and when all is well the C flag will be cleared.

After all of the channels have been measured, we can write the values to the hub for access by the application:

```
report     mov     pntr, pospntr
          wrword   chlus, pntr
          add     pntr, #2
          wrword   ch2us, pntr
          add     pntr, #2
          wrword   ch3us, pntr
          add     pntr, #2
          wrword   ch4us, pntr
          add     pntr, #2
          wrword   ch5us, pntr
```

```

add     pntr, #2
wrword  ch6us, pntr

wrlong  YES, flagpntr
jmp     #findsync

```

This is pretty straightforward. We set up a pointer to the hub array (of words) that holds the channel values and then transfer the readings from the cog. At the end, we write YES (true) to the flag that indicates PPM status to alert the application that the stream is present and the position values are fresh.

Figure 7 shows the output from a test program that reads and displays the PPM stream status and channel values.

```

pub main | c
term.start(RX, TX, %0000, 115_200)
rgled.initx(R_LED, G_LED, 50, OFF)
adc.init(CS, CLK, DIO)
ppm.init(PPM_IN, 1500)
eeprom.init(SCL, SDA)

pause(1)

repeat
term.tx(CLS)
term.str(@Menu)
term.rxfush
c := term.rx
case c
"1" : showdigins
"2" : demoled

```

TESTING 1, 2, 3 ...

I often see posts in the Propeller support forum that go something like this: *"I built my hardware, I wrote my software — it doesn't work. What do I do?"*

Test. Test. Test. The good news is that the Propeller architecture helps us. Earlier this year, my friend and I created and released a Propeller-based WAV audio player (the EFX-TEK AP-16+) that is designed for museums, theme parks, and attraction-based industries like Halloween. It's a beast. Because of the variability of the user base, it has lots of flexibility in its design which means lots of I/O and a fairly tricky PCB.

While John (who also worked for Parallax) was creating the PCB for the first prototype, I wrote a test program to check each section of the board — this was well before a single line of application code was written. Of course, that's a bit of a fib, isn't it? You see, a large portion of the code used in testing moved right into the final application. In fact, as I refined the test program I was refining portions of the application code.

The ability to program the Propeller through a serial port means that we can create a self-hosted test program that uses a simple terminal. As an example for you to play with, I created a test program for this month's project board. When that program starts, it presents a menu using PST (see **Figure 8**) that lets us access/test each section of the board. Here's the main program loop:

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```
"3" : readjoysticks
"4" : readppm
"5" : testeprom
```

Once the objects used by the board are initialized, we drop into a loop that displays the main menu and waits for input. Based on that input, the program will jump to one of the test routines.

The menu is defined as a string and is stored in a **dat** section of the program like this:

```
Menu    byte    "Waldo-4x Hardware Checkout", CR
        byte    "=====", CR
        byte    CR
```

```
byte    "[1] Digital Inputs          ", CR
byte    "[2] Bi-Color LED            ", CR
byte    "[3] Read Joysticks           ", CR
byte    "[4] Read PPM Stream          ", CR
byte    "[5] External EEPROM          ", CR
byte    0
```

Note that the menu string can be spread across lines which allows us to "see" it in the listing. Note, too, that it must be terminated with a zero; we're actually defining the menu as a single z-string and if we omit this, the display could end up a mess. The listing above shows that displaying the menu is simply a matter of passing the address (@) of the menu data to the **str()** method of the terminal object.

We can have sub-menus in the test sections or run code in a simple loop; like this code that displays the values from the VEX PPM stream:

```
pub readppm | idx, c

term.rxflush
term.tx(CLS)
term.str(string(
    "PPM Stream", CR, {
        } "- press X to quit"))

repeat
term.str(string(HOME,
LF, LF, LF))
term.str(string("Active  "))
if (ppm.status == false)
term.str(string(
    "No  ", CR))
else
term.str(string("Yes
", CR, CR))
repeat idx from 1 to 6
term.str(string("Ch"))
term.tx("0" + idx)
term.str(string(" "))
term.dec(ppm.read(idx))
term.tx(CLREOL)
term.tx(CR)

c := term.rxtime(50)
if (ucase(c) == "X")
quit
```

At the top, we clear the terminal RX buffer to remove extraneous keys, remove the main menu, and then display a title string for this test (and note on how to exit back to the main menu). The rest of the code is contained in a loop that displays the VEX connection status and channel values.

At the bottom, you'll see a neat trick with the **rxtime()** method. This method lets us check for input from the user, but only for a specified period (in milliseconds). If no key is pressed in this time, the method returns with a value of -1 (not a valid key). We check the return value for "X" and when that's detected, abort back to the main menu. Until that time, the **rxtime()** method provides a



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nice 50 millisecond update rate for the display — it's a 2-for-1 deal.

Study the test program and put it to use with your own projects. Remember, the time you spend working on test code is not wasted because this code checks your hardware (you need this) and can then be moved into your final application.

That test program I created for the AP-16+ prototype is now used on the other end of the product cycle as a unit tester that is run before we load the application code and ship to our customer.

CODING AND PUBLISHING ARE DIFFICULT!

My friends at *Nuts & Volts* do a spectacular job publishing this (and other) magazines for people like you and me. It's very hard work, taking the frequently wacky style of programmers and putting it into print.

I mention this because after my last column a misguided young man (*ah, to be young and a newbie ...*) took me to task for not providing comments in my code (as it appears in print).

Of course, I comment all of my code. In fact, like most professional programmers, I take pride in the quality of my work and the information that goes into it. That said, the two-column format that is preferred by *Nuts & Volts* and other publications just doesn't lend itself to long program lines so, out of necessity, I strip out the inline comments for the code that is embedded in the article text.

I realize that this stuff can at times get a little heavy, especially the assembly sections. So, those of you really wanting to study the code as you read my column (or others, for that matter), you should open the code that can be downloaded from the *Nuts & Volts* website (www.nutsvolts.com) in your programming editor as you're reading the magazine. Studying the code comments along with the article text will really help solidify your understanding of the project.

Until next time, then, keep spinning and winning with the Propeller. **NV**

JON "JONNYMAC" WILLIAMS

jwilliams@efx-tek.com

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Back To School Time!

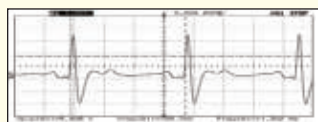
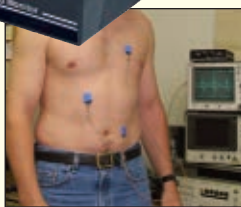
Build It, Learn It, Achieve It, and ENJOY

Electrocardiogram ECG Heart Monitor

- ✓ Visible and audible display of your heart rhythm!
- ✓ Bright LED "Beat" indicator for easy viewing!
- ✓ Re-usable hospital grade sensors included!
- ✓ Monitor output for professional scope display
- ✓ Simple and safe 9V battery operation

September means it's time for the kids to head back to school. You can get kids of all ages ahead of the learning curve and excited about science, health, and electronics with the ECG1C from Ramsey! Not only will putting it together teach them about building their own electronics, but the completed kit is a hands on demonstration of the relationship between electrical activity and the human body. Each time the human heart beats, the heart muscle causes small electrical changes across your skin. By monitoring and amplifying these changes, the ECG1C detects the heartbeat and allows you to accurately display it, giving you a window into the inner workings of the body!

Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors.



The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER!

See the display above? That's one of our engineers, hooked up to the ECG1C after an engineering meeting!

The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs.

Operates on a standard 9VDC battery (not included) for safe and simple operation. Note, while the ECG1C professionally monitors and displays your heart rhythms and functions, it is intended for hobbyist usage only. If you experience any cardiac symptoms, seek proper medical help immediately!

ECG1C	Electrocardiogram Heart Monitor Kit With Case & Patches	\$44.95
ECG1WT	Electrocardiogram Heart Monitor, Factory Assembled & Tested	\$89.95
ECGP10	Electrocardiogram Re-Usable Probe Patches, 10-Pack	\$7.95

Pocket Audio Generator

A perfect test source for stereo line inputs on any amplifier or mixer. Provides 50Hz, 100Hz, 1kHz, 10kHz, & 20kHz tones, plus 32 bit digital pink noise. Great to help you identify cables or left/right reversals! Stereo RCA line level outputs. Uses 2xCR2025, not included.



K8065 Pocket Audio Generator Kit \$32.95

Pocket Vu Meter

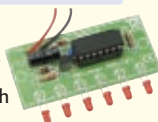
Hand held audio level meter that fits in your pocket! Built-in mic picks up music and audio and displays it on an LED bargraph. Includes enclosure shown. Runs on one 3V Li-Ion button cell, not included. If you ever wanted an easy way to measure audio levels, this is it!



MK146 Pocket Vu Meter Kit \$8.95

Mini LED Light Chaser

This little kit flashes six high intensity LEDs sequentially in order. Just like the K8032 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.



MK173 Mini LED Light Chaser Kit \$15.95

Running Light Controller

Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITT!). Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.



K8032 4-Channel Running Light Kit \$38.95

Digital Voice Changer

This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.



MK171 Voice Changer Kit \$14.95

Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.



MK134 Steam Engine & Whistle Kit \$11.95

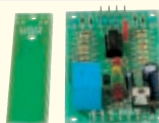
Laser Trip Sensor Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit \$29.95

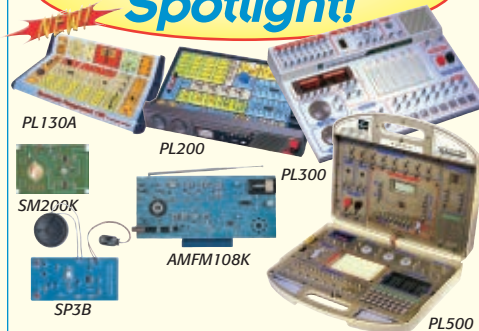
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Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.



K2639 Liquid Level Controller Kit \$23.95

Back To School Spotlight!



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K8071 High Power LED Driver Kit \$14.95

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A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Saint, eats 2-8VAC or 9-12VDC, it's not fussy!



K2655 Electronic Watch Dog Kit \$39.95

Stereo Ear Super Amplifier

Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Incredible gain and perfect stereo separation!



MK136 Stereo Ear Amp Kit \$9.95



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- ✓ Learn It!
- ✓ Achieve It!
- ✓ Enjoy It!

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Vintage Battery Eliminator

Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!

The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filament, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

ABCE1 Vintage Radio Battery Elim Kit \$199.95

Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Receiver Kit \$89.95

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The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit \$19.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

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MK108 Water Sensor Alarm Kit \$6.95

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 Ion Generator Kit \$64.95

Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C Tri-Field Meter Kit \$74.95

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This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

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DVMS8 Digital Voice Message 8Ch Kit \$99.95
DVMS8WT Assembled DVMS8 \$149.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 Voice Switch Kit \$9.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 Touch Switch Kit \$9.95

Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 Laser Light Show Kit \$49.95

USB DMX Interface

Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.

K8062 USB DMX Interface Controller Kit \$67.95

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 Tickle Stick Kit \$12.95

USB Experimenter's Kit

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. The mystery is solved with this kit!

K8055 USB Experimenter's Kit \$49.95

Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 Sniff-It RF Detector Probe Kit \$27.95

Ultimate 555 Timers

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

All connections are easily made through terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A Through Hole 555 Timer/Osc Kit \$24.95
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OBDII CarChip Pro

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 CarChip Pro OBDII Monitor-Asmb \$99.95

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Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

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Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base, 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm! Tube kits also available.

IN14TM Teak Maple Nixie Clock Kit \$329.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13 HV Plasma Generator Kit \$64.95

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SG7 Speed Radar Gun Kit \$69.95

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Asmb.

PR2 Broadband RF Preamp \$69.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U 3-In1 Multifunction Solder Lab \$129.95

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Video Buffer
- ✓ Game Clock
- ✓ LCD Backlight

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: Q&A@nutsvolts.com

HUM DETECTION

Q For more than 30 years, I was a design engineer in the electronic communications industry, so I feel I should be able to undertake most projects when so inclined. However, the problem we (my family and I) now have has me stumped. For some time, we have experienced a low-level low frequency hum (say 20 Hz to 60 Hz range) which pervades the house 24/7. This sometimes makes sleeping problematic for us.

Having carried out some investigation and ruled out internal sources, I now realize this is a national (if not worldwide) problem with sources as esoteric as the Russian VLF submarine communications, gravitational waves, overhead power lines, and subterranean gas distribution being suggested.

However, I believe the source/s to be more prosaic such as

machinery at a local industrial site or beat frequencies created by ventilation fans at local chicken producers.

The latter types of source are located several miles away and thus the higher frequencies in the noise spectrum are attenuated leaving only the LF component (which if captured on a spectrum analyzer could become a 'signature').

The difficult problem is to determine the source direction at a reasonable cost. In principle, a mobile detector could direction-find the source from two/three locations and a map could be used to determine the point source. The latter would be difficult because the hum is mysteriously only detected inside the house.

Perhaps the house acts as a type of resonant cavity. Allegedly, churches with their high ceilings are even better hum detectors.

Any practical ideas from you or the readers would be helpful.

— John Hobday

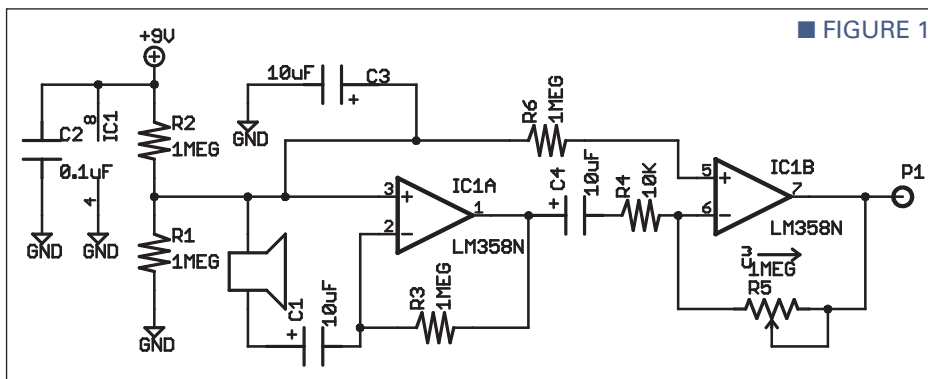
A Since the hum is only audible inside the house, the noise must be traveling through the ground.

Therefore, seismic sensors should be used to find the direction. The procedure would be to place two sensors in the ground, connected to the two inputs of a dual channel oscilloscope. When the signals of the two channels coincide, the sound direction is at right angles to the line between the sensors.

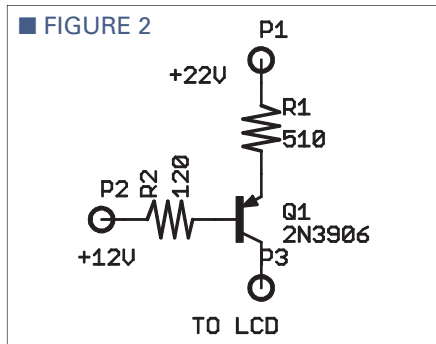
If that is not enough to find the source, move the sensors until there is a significant difference in the direction of the sound. A US Geological Survey map will be helpful in this endeavor (available from most camping and hiking supply stores). Oops, I see you are in the UK but I am sure similar maps are available.

This URL shows how to make your own seismic sensor from a speaker with a weight glued to the cone: www.techlib.com/electronics/seismic.htm. You can use the circuit shown on the site, or I think **Figure 1** will be more sensitive.

In **Figure 1**, I used an LM358 op-amp because it's cheap and commonly available but if circuit noise is a problem, the SSM2135 op-amp is low noise and available from Digi-Key. The first stage should give 60 to 80 dB gain and the second stage has 40 dB available if you need it. I suspect the seismic hum is high level so you won't need maximum gain. With so much gain, the layout



■ FIGURE 2



will have to provide isolation or it will oscillate. The web article suggests gluing a post to the speaker cone and attaching it to the cover of a glass jar. You can put the circuit and battery in the jar to make a sensor that can be partially buried in the ground for good sonic conductivity.

BAND SAW BLADE WELDER CIRCUIT

Q I'm looking for a circuit that uses a 12 VDC car battery to butt weld 1/2" band saw blades.

I'm not sure if it can be used to weld bi-metal blades, but the carbon steel should work fine.

There is a commercial unit shown at <http://advancecarmover.thomasnet.com/item/band-saw-blade-welder-2/item-1017?&forward=1> and PDF manuals there for downloading and viewing. The price seems a bit high for this unit.

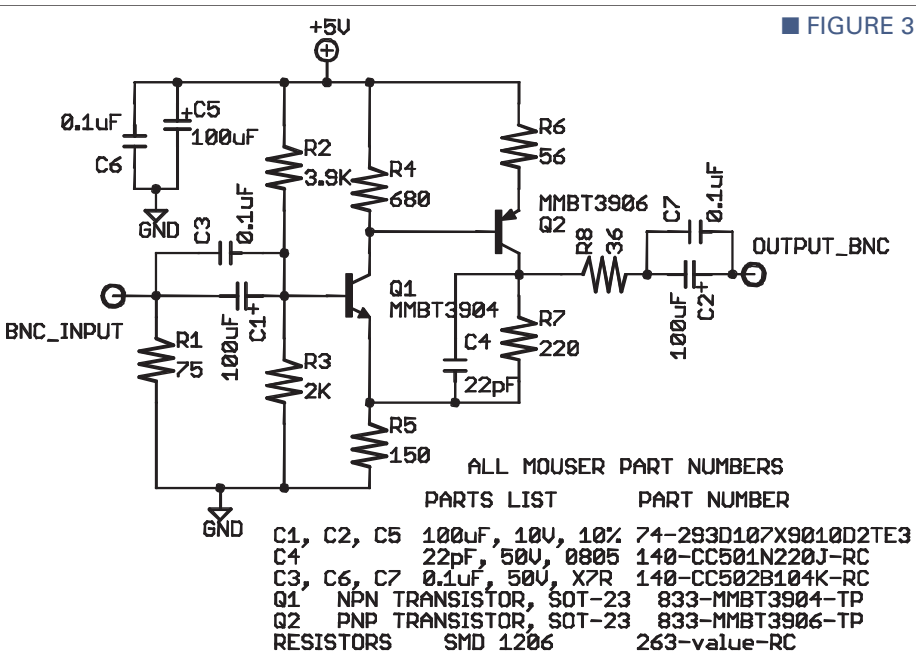
Do you have any ideas on a circuit that would allow me to safely duplicate this blade welder?

— Larry Kraemer

A There is no circuit; all you need is a switch capable of 500 amps to connect the battery to the blade. The jig that keeps everything in alignment is the key that makes it work.

LCD BACKLIGHT

Q I'm repairing a portable DVD player and I want to replace the defective LCD screen.



I found that a 7" LCD display from a digital photo frame 480 x 234 works great and will replace the defective display in the DVD unit. I believe that the photo frame LED backlight works on approx. 12 VDC @ 80 MADDC and the DVD player works on approx. 22 VDC @ 40 MADDC. The problem is the original LED backlight has 21 LEDs in series and the replacement LED backlight only has 15 LEDs in series.

My issue is that when the unit is turned off, the power for running the LEDs is 12 volts DC so the backlight is lit up even when it's off. When you turn the unit on, the power goes to approximately 22 volts DC (that's the reason the original LED stayed off). Is there a circuit I could add that would not allow 12 volts DC when it's turned off? And when it's turned on it would supply anywhere from 12 volts DC to 22 volts DC? This circuit would have to be small as there isn't much room to add a lot of components.

Thanks in advance.

— Jeff Miller

A The circuit in **Figure 2** should do the job. Since the emitter and base are at the same potential when the power is off, the transistor will be off. When the voltage drive goes to

22 volts, 40 mA will be sent to the LCD backlight. R2 allows the backlight to go above 12 volts and you can short it out to save room.

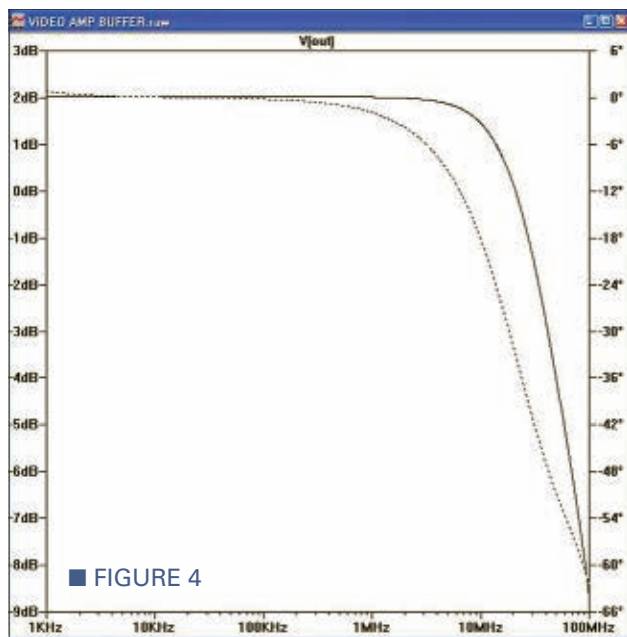
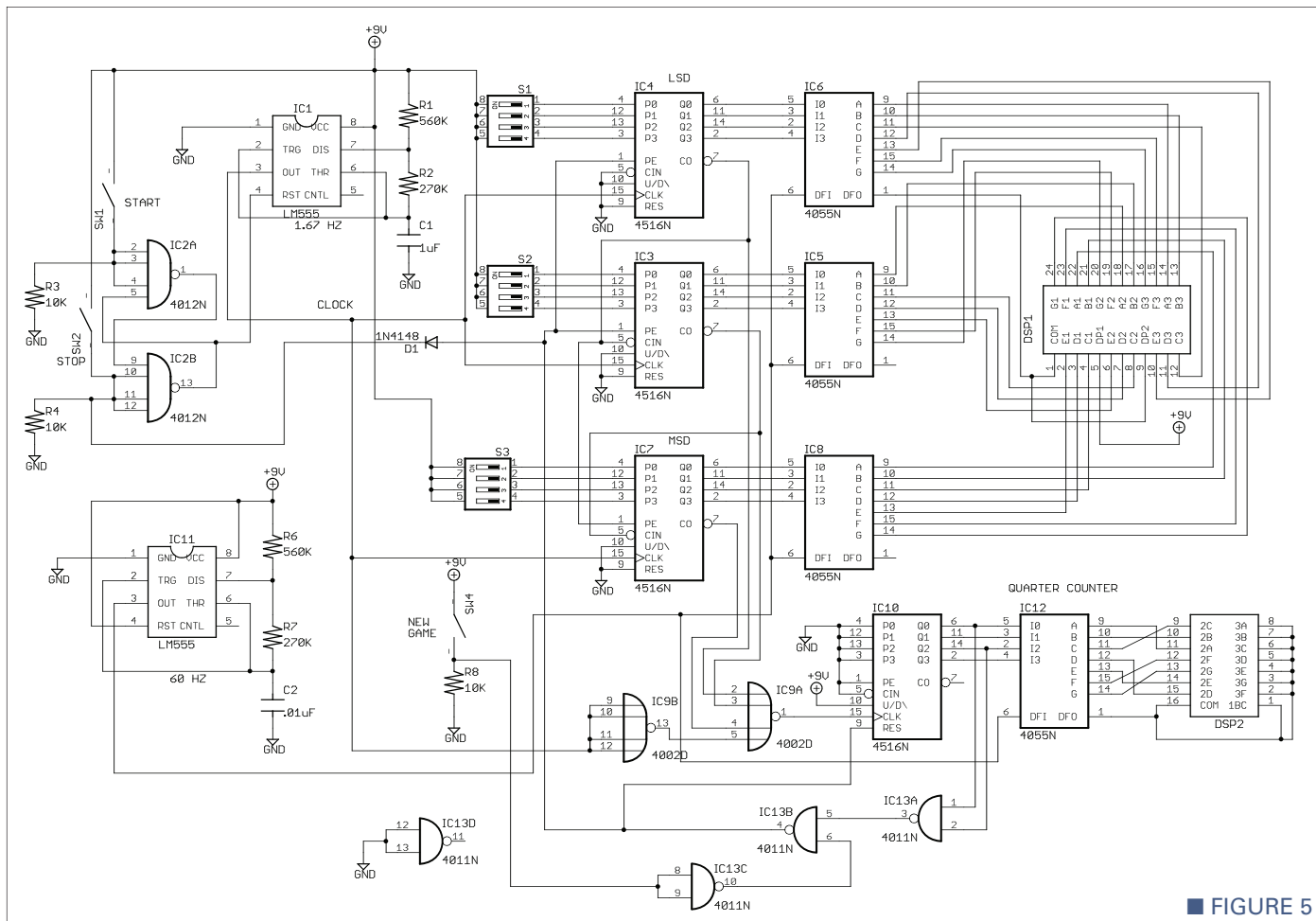
VIDEO BUFFER

Q I have what seems to be a simple problem, but my search for an answer has not given me good results. I have six security cameras around my yard and they all feed a DVR. Every couple of years, I lose at least one camera and the DVR to lightning strikes. While replacing a camera or two does not break the bank, the cost of a DVR is quite a different matter.

Although I could probably just use MOVs or some other passive device, I thought a simple, inexpensive, low power video buffer would be in order; a sacrificial device as it were. I say low power because my electric bill is already high and I am working to reduce it, not increase it. The cameras are strictly video, no modulation involved. Any ideas?

— Joe Heck

A I think metal oxide varistors at the camera power input and video output, plus another MOV at the DVR video input would



gain is 2 dB and the bandwidth is 10 MHz. The maximum output is one volt p/p and if that is exceeded, there will be distortion due to saturation delay in Q2.

Q I'd like to make a game clock similar to the ones used for basketball games for my daughter. Can you help me with how I could accomplish this?

Not having played basketball or paid attention when watching, I don't know if the clock counts down or

up, so I will wing it and assume a count down clock with four quarters. High school games have eight minute quarters, so two digits counting tenths of minutes will suffice.

Hold on, a tenth of a minute is six seconds – that is too long. I will have to have three digits, counting hundredths of a minute. A second counter will keep track of quarters. Single digit LCDs are not available, so I will use a 2-1/2 digit display and use the middle digit for the quarter number.

In **Figure 5**, I have a 555 oscillator producing 100 pulses per minute (1.67 Hz). IC2 is a flip-flop to stop and start the clock. I could have used a 4011 quad NAND with two gates left over; you can do that if you want.

I show DIP switches to set the starting time for the count down counters but if you know the time is going to be the same all the time, you can hard-wire it. When all three

counters (IC4, IC3, and IC7) have reached zero, IC9A clocks the quarter counter, IC10. When the quarter count reaches 5, IC13A decodes that number, resets all the counters, and stops the clock via D1.

There is no power-up reset so the game master will have to press the "new game" button to start. The new game button can be pressed at any time to terminate a game and start over. IC11 is a 555 oscillator running at 60 Hz to drive the LCD displays.

If you build this, let me know how it turns out. The LCD runs on five volts, but there is no maximum specified so I think it will work on nine volts. I did not breadboard this, so if anyone finds a flaw in my logic, please let me know.

BLINKING TAILLIGHT REVISITED

Q In addition to that blinking taillight brake mentioned in the June '10 Q&A, how about increasing the blink rate and light intensity in proportion to the car's deceleration?

Perhaps using one of those accelerator sensing chips I see advertised and an additional/optional circuit for external super bright LEDs?

A timer/op-amp hardware solution seems possible (well, for someone much cleverer than I it might seem possible!!).

— Brian Stoller

A Increasing the blink rate with deceleration is a good idea. However, even though the acceleration IC is cheap, the development hardware and software is expensive, so I won't go there.

Besides, I subscribe to the KISS principle and a rheostat with a weighted knob will do the trick. Replace R3 in Figure 5 of the June issue with a 50K rheostat (potentiometer) oriented so that the weight swings forward and connected to reduce the resistance. You can rotate the rheostat to get the desired resting blink rate.

A similar, lower resistance rheostat in series with the taillight could be used to change the brightness; although the resting brightness would be reduced. **NV**

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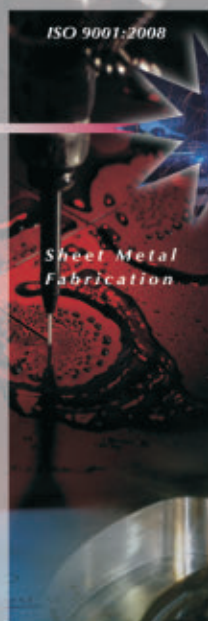
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Continued on page 77

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MAKE THE PLL FREQUENCY SYNTHESIZER WITH PIC CONTROL

BY DAN GRAVATT

A frequency synthesizer (signal generator) is a device which generates a very stable waveform at a user-selected frequency. They are very handy when you need such a waveform as an input to another circuit such as an audio mixer, a radio transmitter, or digital logic. This design is optimized for use with digital circuits but can easily be adapted to audio or radio frequency applications. The short list of requirements I had for this synthesizer included a wide frequency range (up to 30 MHz), small frequency steps (1 kHz), high accuracy, 50% duty cycle output, and a simple user interface for selecting the frequency. The end result (Figure 1) met all these requirements at a cost of around \$70 including the custom-made circuit board. There are some ready-made synthesizer chips on the market including the LTC6904 — a neat little eight-pin device with an I²C interface — but these didn't have the frequency steps I wanted or had insufficient accuracy.

Frequency Magic

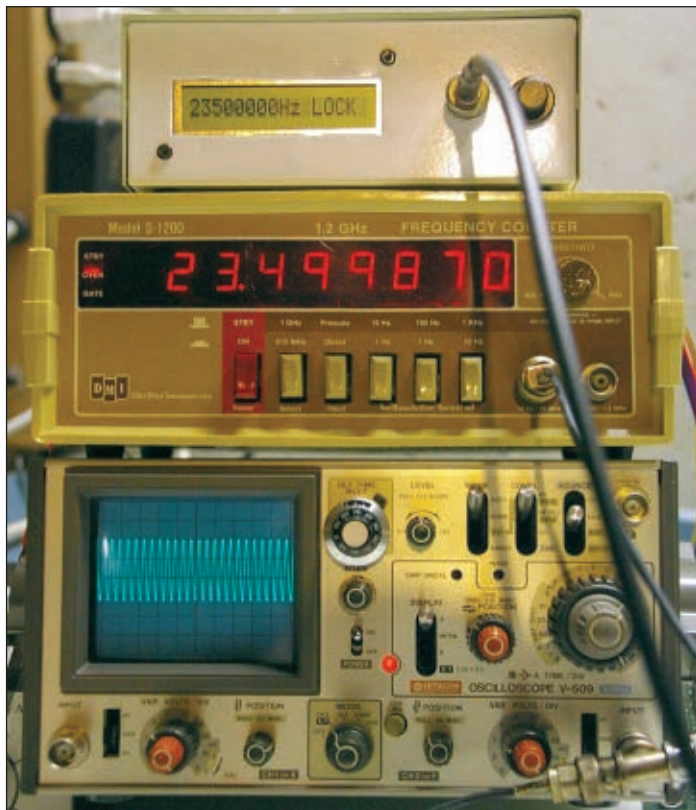
A phase-locked loop (PLL) can be used for many applications, including frequency multiplication. In a typical

application, a PLL continually attempts to synchronize its internal voltage-controlled oscillator (VCO) with an external frequency applied to the PLL. A phase comparator in the PLL compares the two frequencies and generates an error voltage which is applied to the VCO to “lock” the VCO frequency and phase to the external frequency and phase. This is a pretty neat trick all by itself, but it becomes more interesting if we place a frequency divider between the PLL's VCO output and its phase comparator input. This makes the phase comparator think the VCO is oscillating much slower than the external frequency, by a factor equal to the frequency division ratio. The phase comparator then outputs an error voltage to the VCO which raises its frequency to equal the external frequency multiplied by the frequency division ratio. Once the PLL locks onto this multiplied frequency, we have a very accurate multiple of the external frequency with a 50% duty cycle.

Component Selection

I selected the 74HC4059 programmable divide-by-N counter/divider to set the frequency division ratio for the PLL. This chip can divide its input frequency by any number up to 15,999 and has 16 frequency-setting “Jam” inputs which are easily interfaced to a microcontroller.

I settled on using the CD74HC7046 PLL for this project. This chip has a wide frequency range (up to 38 MHz), a good “lock” range, and also has a “lock detect”



■ FIGURE 1. The PLL-based synthesizer (top) in operation, with frequency counter and oscilloscope measurements of its output.

output which provides confirmation that the PLL has indeed locked at the desired frequency. The lock detect output was the main reason I picked this PLL, as it enables the synthesizer to operate over a frequency range much larger than the PLL lock range – more on this later. The accuracy of the entire synthesizer is dependent on the accuracy of the external frequency applied to the PLL, and for this I selected a 1.000000 MHz TTL clock oscillator. A trio of 74HC390 dual decade dividers are used to scale the oscillator frequency down to 100 kHz, 10 kHz, 1 kHz, 100 Hz, 10 Hz, and 1 Hz, and a 74HC151 8-to-1 multiplexer is used to select which frequency is applied to the PLL. During prototyping, I discovered that I could achieve the entire frequency range I wanted using only the 10 kHz and 1 kHz inputs, but I left the 8-to-1 multiplexer and the third dual decade divider in the design in case you need a different frequency range or frequency step size for your application. The user interface I selected consists of a 16 character LCD to display the frequency, a 12 button matrix keypad for direct frequency entry, and a single potentiometer to adjust the PLL's VCO frequency. After adding up all the I/O lines required to control the 74HC4059 divider, the 74HC151 multiplexer, the LCD, and the keypad, I selected the PIC16F877A 40-pin microcontroller as the brains of the synthesizer. All 33 of its I/O lines are used in this project.

I wanted the output of the synthesizer to be able to drive pretty much any reasonable circuit that might need a frequency input, but the VCO output of the PLL can't deal with much of a load before it begins to affect its frequency stability and accuracy. An op-amp buffer was required, and I wanted a really good one with more than enough gain-bandwidth product at the 30 MHz maximum frequency. I also wanted single-supply operation with rail-to-rail outputs and a decent output current capability. I settled on the Analog Devices AD8044 quad op-amp which meets all of these requirements and then some.

Figure 2 is a block diagram of the entire synthesizer.

I deliberately selected through-hole (DIP) components for this project to ease assembly for folks who aren't comfortable with surface-mount parts; however, all of these components are also available in surface-mount packages.

PLL Multiplier Operation

The PLL frequency multiplier consists of the 74HC7046 PLL, the 74HC4059 divider, a resistor and capacitor to set the PLL's VCO frequency, a resistor and capacitor to filter and smooth the PLL's phase detector error voltage (referred to as the loop filter), and a

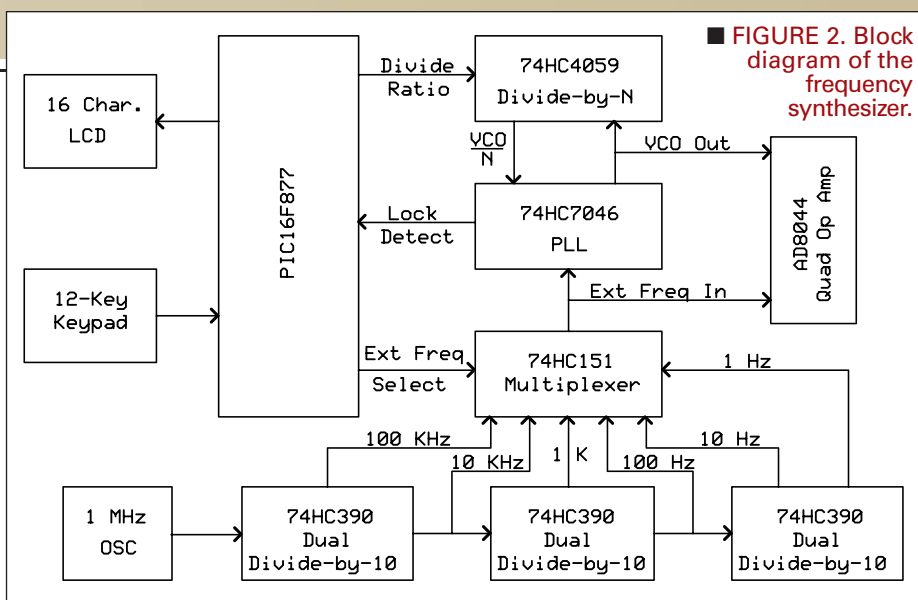


FIGURE 2. Block diagram of the frequency synthesizer.

capacitor to filter the lock detect output of the PLL. All of these passive components should be optimized for the frequency range over which the PLL is expected to lock, and since the synthesizer range is relatively large (300 kHz to 30 MHz), I had to make some compromises.

I selected the loop filter capacitor and the lock detect output capacitor values to be large enough to filter effectively at the low end of the frequency range. They are far larger than necessary for the high end of the frequency range, and as a result it may take the PLL a significant fraction of a second to lock at high frequencies due to the charging time of these capacitors. The loop filter component values also determine the amount of damping of the VCO output, so the amount of “ringing” in the waveform depends in part on these values.

The large frequency range I wanted posed a particular problem for the resistor and capacitor setting the VCO frequency, as there just isn't any one combination which will work across the entire range. One of these components has to be variable, so I chose to use a variable resistor and a fixed, small-value capacitor. I found that a capacitor value of 27 pF was necessary to ensure operation up to 30 MHz. This capacitor should be a high-stability ceramic or silver-mica type. To make this small capacitance work at the low end of the frequency range, a large resistance is needed. The 74HC7046 PLL datasheet specifies a minimum of 3K ohms for this resistor, and I used a 250K pot. I also placed a small fixed-value resistor in series with the pot so the resistance can never go to zero.

Now that the PLL relies on the user to set this resistance manually in order to lock onto the desired frequency, there has to be a way for the PLL to tell the user when they have made the proper adjustment. This is the purpose of the PLL's lock detect output which consists of an irregular stream of pulses when the PLL is out of lock, and a constant logic-high when the PLL is locked. I decided to use the PIC's Timer0 external counter input (pin RA.4) to constantly look for pulses on the lock detect output. If the Timer0 count is zero, we know the PLL is locked, and “LOCK” will be displayed on the LCD.

The 74HC4059 divider has a number of counting “modes” which are described in a rather confusing manner in the datasheet. The one I used for this project is Mode 10 with a maximum division ratio of 9,999 – more than adequate for this application. I selected this mode because it offers the simplest way for the PIC to send the division ratio data to the divider. In Mode 10, the 16 Jam inputs are grouped into four four-bit binary-coded-decimal digit inputs representing the four digits of the division ratio. The PIC only needs to do a little arithmetic and some bit manipulations to calculate this ratio and send the BCD data to the divider.

PIC Code

The code for this project is written in PICBASIC PRO (available from microEngineering Labs at www.melabs.com and is included with the downloads for this article at www.nutsvolts.com). It consists primarily of a loop to scan the keypad for input, record key presses into an array variable, display the frequency on the LCD, and monitor the Timer0 count to check if the PLL is locked. Frequencies must be entered in Hertz – not kiloHertz or MegaHertz. Once a frequency is entered, the code jumps to a subroutine which parses the contents of the array variable. If the frequency is within the range of the synthesizer, the code selects the necessary external frequency on the 74HC151 multiplexer, then calculates and sends the divide ratio to the 74HC4059. The code then returns to the main loop.

The frequency resolution is set by the external frequency (the step size, either 10 kHz or 1 kHz), so if a frequency with finer resolution than this step size is entered, the extra resolution will be ignored. For example, with a 1 kHz step size, a frequency entry of 123,456 Hz will be truncated to 123,000 Hz. If the entered frequency is outside the range of the synthesizer, an error will be displayed, and the display will be blanked to accept a new entry. The last valid entered frequency will continue to be output while waiting for the new entry. Because the frequency is stored, calculated, and displayed as an array of characters (rather than one numeric value), the code isn’t subject to the limitations of a 16-bit word-sized variable.

When first powered up, the synthesizer frequency defaults to 200 kHz (a holdover from my early tests with the 74HC4059) because the PLL can’t and shouldn’t be forced to output 0 Hz. However, this default frequency will not be displayed. Since the position of the VCO adjustment pot is unknown, the actual output frequency is undefined until the user inputs a valid frequency and then adjusts the pot to achieve frequency lock.

The frequency entry keypad is laid out just like a telephone keypad, with the Enter key where the # key is on a telephone. Only 11 of the 12 keys on our keypad are needed, so the * key is unused. To prevent unpredictable characters from being entered if the * key is accidentally pressed, this key acts like another 0 key.

Make sure to look at the code listing for more insights into how the keypad is scanned for inputs, the frequency input is parsed, the divide ratio calculations are performed, and the display is updated. I put in plenty of

comments to make functions clear and to facilitate any modifications you might want to make. Note that this code far exceeds the 31-line limit of the demo version of PICBASIC PRO (the first of my projects to do so), so if you want to modify and recompile it, you’ll need the fully functional version of the compiler.

Construction

Building this circuit (**Figure 3**) is impractical without a custom printed circuit board (PCB), though I did breadboard the circuit during prototyping with predictably messy results (**Figure 4**). A good quality circuit board with a ground plane is essential for clean, stable operation at the high frequency end of the synthesizer’s range. The layout of the PLL, divider, and op-amp circuitry on the board was done with this in mind, minimizing trace lengths and keeping component spacing tight. The ground plane is kept away from the op-amp

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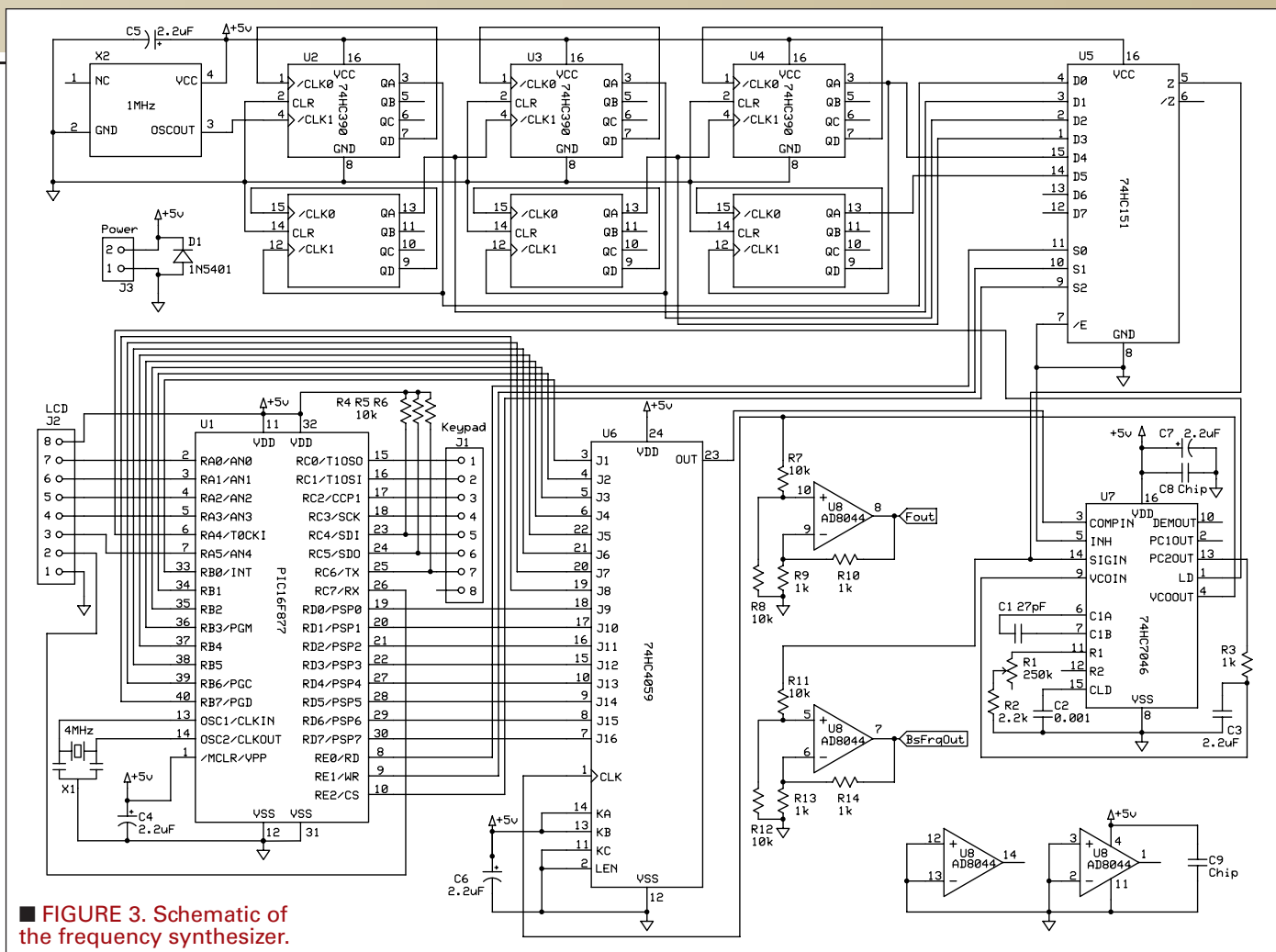
ITEM

PIC16F877A microcontroller, DIP-40
74HC4059 programmable divider, DIP-24
74HC7046A phase-locked loop, DIP-16
74HC151 multiplexer, DIP-16
(3) 74HC390 dual decade counter, DIP-16
AD8044 quad op-amp, DIP-14
74HC14 hex Schmitt trigger DIP-14 (optional)
1.000000 MHz half-size TTL oscillator
4 MHz ceramic resonator with caps
1N5401 diode
(5) 2.2 μ F tantalum capacitors
27 pF NP0 ceramic capacitor
0.001 μ F ceramic capacitor
(2) 0.1 μ F surface-mount (1206 chip) capacitors
(7) 10K ohm 1/8 watt resistors
2.2K ohm 1/8 watt resistor
(5) 1K ohm 1/8 watt resistors
250K ohm potentiometer
12-key matrix keypad
16 character by 1 line parallel-interface LCD
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PART NUMBER

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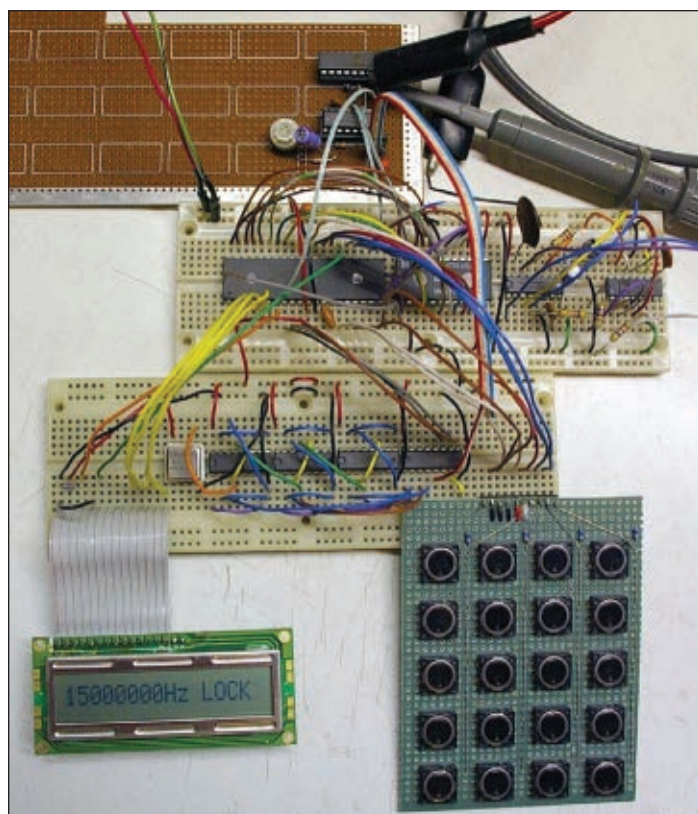
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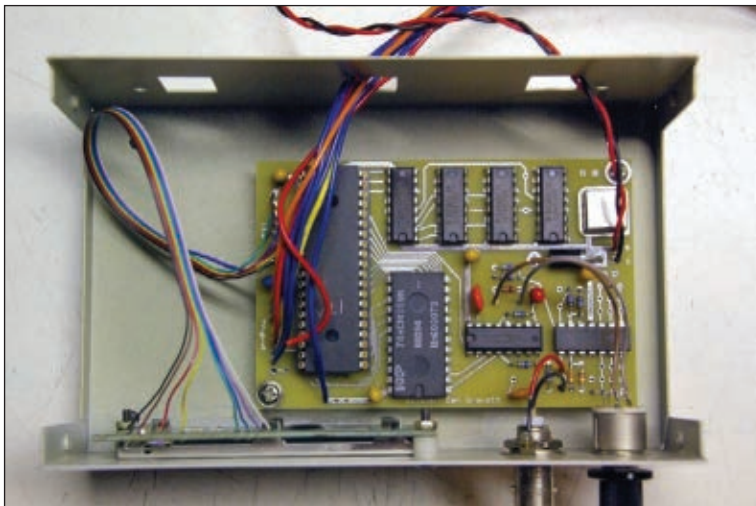
inputs and VCO pins on the PLL to minimize stray capacitance at these sensitive high frequency circuit nodes. I recommend against using sockets for any of the chips except the 16F877 due to the high frequency signals present in the circuit. The ExpressPCB file for the PC board I designed (**Figure 5**) is also available at www.nutsvolts.com.

Power supply bypass capacitors are distributed across the board to prevent glitches and minimize ringing on the output signal. The datasheet for the AD8044 also recommends installing a surface-mount (chip) capacitor directly from the op-amp's positive supply (pin 4) to the adjacent ground plane to further enhance stability. I installed chip capacitors on the back side of the circuit board at the positive supply pins for the op-amp and the PLL. A shielded enclosure is highly recommended, as well as a good, high frequency output connector such as a BNC.

The voltage dividers formed by resistors R7-R8 and R11-R12 are necessary to prevent the VCO output voltage swing (zero to five volts) from exceeding the maximum input voltage rating of the op-amps. The gain of the op-amps is then set by feedback resistors R9-R10 and R13-R14 to restore



■ **FIGURE 4. Breadboard prototype of the frequency synthesizer. The PLL and op-amp circuits were built on the general-purpose PC board (at top) for stability.**



■ **FIGURE 5.** PCB for the frequency synthesizer mounted in its enclosure.

the five volt voltage swing at the output of the synthesizer. Any unused op-amp inputs should be tied to ground.

Modifications

I designed a fair amount of flexibility into the schematic

and PCB to make this project as useful as possible. As stated earlier, the third 74HC390 dual decade divider which provides 10 Hz and 1 Hz signals is optional and can be left out if desired. All of the decade divider outputs are connected to the 74HC151 multiplexer so the PIC code can be modified to use any of them as the PLL's external frequency. This could be helpful if you need lower frequencies or smaller frequency steps than the "stock" design. For example, you could create a 20-20,000 Hz audio frequency generator with a 1 or 10 Hz step size by increasing C1 to 1 μ F or so, adjusting the loop filter and lock detect filter component values, and adding a few lines of code in the SELECT CASE argument to accept frequency entries that are two, three, or four digits long.

Two additional op-amps in the AD8044 are available for use as filters or wave shapers, and pads are provided for connecting components to those op-amps. Active filters can be used to convert the square wave output to a sine or triangle wave. These different waveforms are particularly useful for audio mixer work as each has a different spectral (harmonic) content. A sine wave is a single frequency with no harmonics. Square waves and triangle waves contain a single frequency plus an infinite number of odd harmonics of

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that frequency, but the relative amplitudes of the harmonics in a square wave are different from those in a triangle wave.

R4 through R6 are pull-up resistors for the column scan lines on the keypad; these can be omitted if the keypad you use has built-in pull-up resistors.

I had hoped to include a high quality triangle wave output from the 74HC7046 PLL in addition to the square wave output, but design trade-offs prevented this. This PLL has two different phase comparator circuits, but the lock detector only works with phase comparator 2, and this comparator does not produce triangle waves. Phase comparator 1 produces a nice triangle wave in addition to the square wave.

If you plan to use the synthesizer over a smaller frequency range that is within the PLL's lock range and you need the triangle wave output more than the lock detector output, you can re-route the 74HC4059 divider output to phase comparator 1. The triangle wave output will be available at the PLL's VCOin pin.

If you intend to use the synthesizer only as a square wave signal source for digital circuits, the AD8044 op-amp isn't absolutely necessary. However, I still highly recommend a digital buffer between the PLL's VCO output and the outside world. This can be accomplished

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Counting Pulses With Timer0 by Chuck Hellebuyck, N&V, May 2009

www.analog.com/static/imported-files/Data_Sheets/AD8044.pdf

focus.ti.com/docs/prod/folders/print/cd74hc7046a.html

www.standardics.nxp.com/products/hc/datasheet/74hc4059.pdf

by installing a 74HC14 hex Schmitt trigger in place of the AD8044, with the following modifications:

- Clip off pin 4 of the 74HC14, then solder the 74HC14 to the board in the same orientation as the AD8044 (pin 1 is the square pad).
- Place a wire jumper from the trace on pin 7 to ground, and a jumper from the trace on pin 14 to the pad for pin 4. This establishes power and ground connections to the 74HC14.
- Place a wire jumper across the pads for resistor R11, and a jumper from the trace on pin 4 of the 74HC7046 to the trace on pin 9 of the 74HC14. Omit resistors R7-R10 and R12-R14.

The buffered output of the PLL's VCO is then available at the trace on pin 8 of the 74HC14, and the buffered output of the external frequency input to the PLL is available at the trace on pin 6. **NV**

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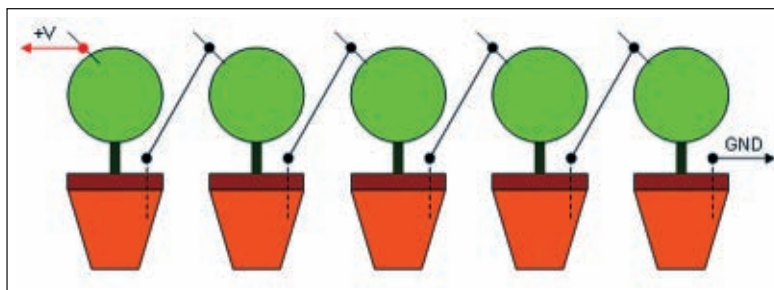
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FLOWER POWER

BY CARLOS COSSIO

As incredible as it may sound, the purpose of this project is to power a device from a set of potted plants. A 'bio-energy battery' of this sort may remind you of the well-known potato and lemon batteries where two electrodes made from different metals (typically copper and zinc) are stuck into a piece of fruit to form a sort-of simple galvanic cell. However, in this case the cells of the battery draw their energy directly from the plants, rather than from an electrochemical process.



■ FIGURE 1. Block diagram showing the serial connection procedure among several plants. Like any standard battery, every plant has a positive and negative terminal.

There is no question that our plant battery supplies free energy. It may not be a lot, but it is still energy. As stated, this energy is generated directly by the plants and will continue to supply energy as long as they remain alive. The operating principle of our potted plant battery is currently the subject of study at several research centers. These voltages have recently been attributed to a pH difference between xylem tissue and soil content.

A potential difference of approximately 400 mV can be measured between the plant and the soil it grows in. This voltage source can supply a power of approximately 0.8 microwatts, regardless of whether it's a small

houseplant or a large bush.

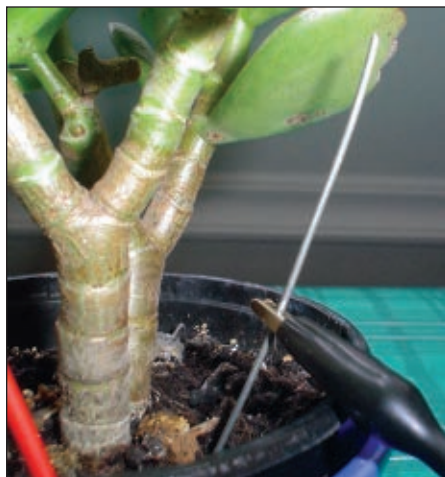
Serial Connection

Certainly, this is far too little power for most applications, but it is enough to operate a simple LCD timer. Of course, this requires connecting several plants in series to form a battery. It is important to state that the series connection would not work if the plants were all in the same pot, since in that case the pot soil shared by the plants would act as a sort of 'common ground' in the literal sense. The pots must also be located on an electrically non-conductive surface. The schematic in

Figure 1 shows how five potted plants can be connected in series to form a bio-energy battery with five cells.

Five plants are enough to power an ultra-low power MSP430F2013 available from Texas Instruments. Just like a standard battery cell, each plant has two terminals. The first terminal is located on a branch of the plant and is formed by sticking a needle or small pin through the branch, then connecting an alligator clip to it. (See Photo 1.) The other

■ PHOTO 1. A needle stuck into a plant branch works as the positive terminal of the potted plant battery.



■ PHOTO 2. A closer view of the ground terminal. A long metal rod inserted in the soil of the plant, then connected with an alligator clip works as the negative terminal of the battery.



■ **PHOTO 3.** To test the voltage supplied to the circuit, I connected a voltmeter to the rightmost and leftmost terminals of the battery. The voltage supplied by the five potted plants was around 3.2 volts in open circuit.



■ **PHOTO 4.** The LCD timer running solely with the energy supplied by the plants. Most of the time, the microcontroller is in deep sleep mode and wakes up every second only to update the LCD display.

terminal is in contact with the pot soil. A relatively long metal rod stuck into the dirt — also connected with an alligator clip — is sufficient for this purpose (**Photo 2**).

Five potted plants are connected together in this way to build a series circuit like the one shown in **Photo 3**. The voltage supplied is around 3.2 volts in open circuit. Now, the MSP430 LCD timer with ultra-low power consumption can be connected to the outer terminals of this battery. The positive terminal of the LCD timer is connected to a free branch of the first plant in the series, while the negative terminal is connected to the soil of the last plant in the series. As soon as the power is connected, the LCD timer starts counting up from zero to nine every second over and over again (see **Photo 4**).

Good for the Environment

Most remote environmental sensing networks (for climatic and wildlife monitoring) rely on batteries which must be maintained and replaced on a regular basis. These networks would benefit from self-sustaining power sources. By using the bioelectric properties of living plants, it is possible to tap a natural source of energy to power electronic circuits, thus eliminating the need for conventional chemical batteries. This energy source could



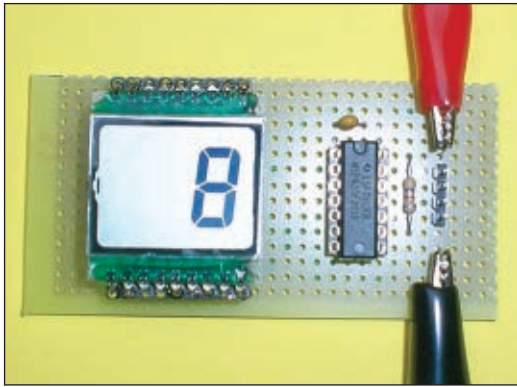
■ **PHOTO 5.** The “*crassula arborescens*” plant exhibits very good bioelectric properties. Every ‘single cell’ of the plant battery is able to supply up to 800 millivolts in open circuit. Connecting more cells in series will increase the voltage supplied.

foster the development of new applications for electronics and expand the number of locations in which they operate. As an example, Voltree Power (www.voltreepower.com) is now deploying the first applications of this novel technology from forest fire detection and prediction to agricultural monitoring using ultra-low power wireless mesh networks with built-in sensors.

The Perfect Plant

It is well known that during Thomas A. Edison’s process of inventing the incandescent light bulb, he and his team travelled around the world to find the right kind of filament. He tried thousands of different ones and sometimes exotic materials until he discovered exactly what he needed. Well, I almost had the same experience. Not all plants exhibit the same bioelectric properties. I put different kinds of office and house plants under test until I found the right one for my project. Its scientific name is ‘*crassula arborescens*’ and it’s originally from South Africa. Fortunately, it is quite common and very easy to find in any flower shop.

Most office and house plants supply a voltage in the range of 200 mV to 400 mV, but our succulent plant is able to supply up to 800 mV in open circuit as shown in **Photo 5**. This is ideal since it reduces the number of



■ **PHOTO 6.** Close-up view of the LCD timer hardware. Simplicity is the key to be able to run an electronic circuit with such a tiny amount of energy.

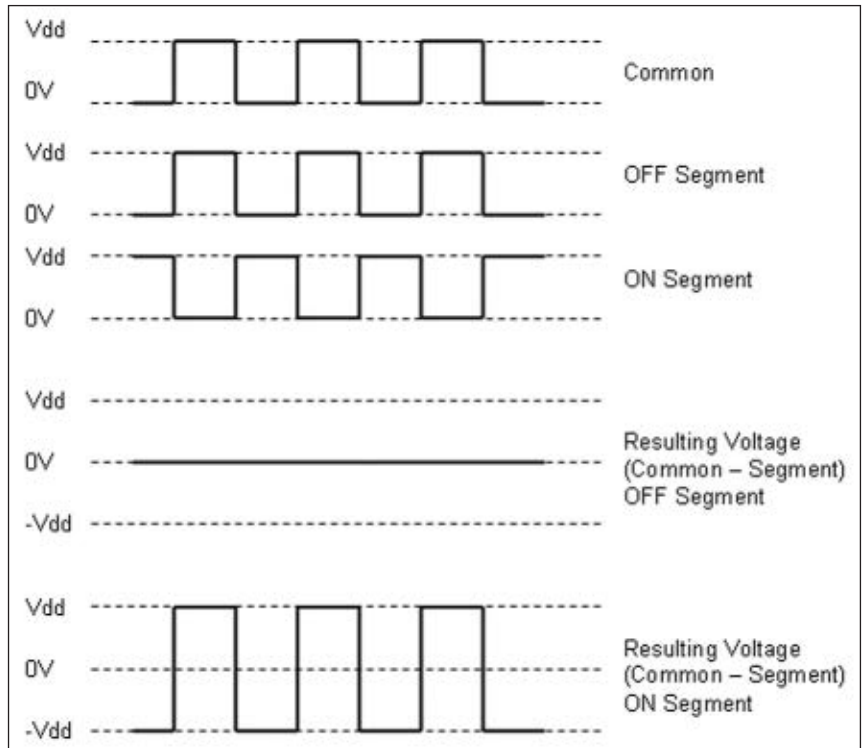
potted plants required to form a battery.

Hardware Design

As mentioned, the hardware design is built around the MSP430F230 microcontroller. It has an impressive ultra low-power operation mode and a Dual-In-Line (DIP) package very suitable to the hobbyist (see **Photo 6**).

The MSP430F2013 lacks an LCD controller, so this task is done by software with the help of a watchdog working as an interval timer. The VIKAY LCD I1045 is a two digit static LCD, which means each segment must be driven by a dedicated I/O line. Since the number of available outputs in the MSP430F2013 is quite limited, only the least significant digit is driven requiring port P1 of the microcontroller to be dedicated to drive the LCD.

The main advantage of static drive is that it is simple to implement. You only have to worry about which segment line to turn on and off, while activating the common signal all the time. Another advantage is that



■ **FIGURE 2.** Waveforms of a static LCD driver. Although the MSP430F2013 lacks the LCD controller hardware, this feature can easily be implemented in software, minimizing power consumption.

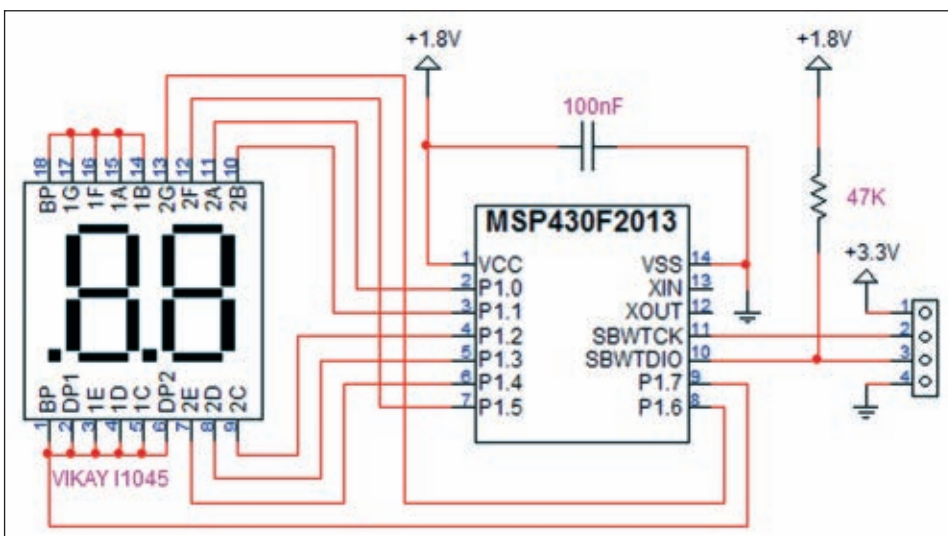
voltage levels can go from rail to rail and do not require multiple intermediate levels as is needed when driving multiplexed LCDs.

The disadvantage is that it requires more pins. Every segment must have a segment line tied to it, and segment lines are connected to pins on the microcontroller. It is important to connect all unused segments (most significant digit of the LCD) to the backplane and not allow them to float to prevent the appearance or partial activation of an OFF segment (also known as “ghosting”).

Figure 2 shows an example of static LCD waveforms.

If the segment waveform equals a common waveform, then the segment is in the OFF state. If the segment waveform equals an inverted common waveform, the segment is in the ON state.

In regards to the clock source of the MSP430F2013, there is not a crystal or external resonator. This is because (in order to keep power consumption to a minimum) the built-in very low power oscillator (VLO) is used. Finally, there is a Spy Bi-Wire connector for programming and debugging purposes. **Figure 3**



■ **FIGURE 3.** Schematic of the LCD timer based on the ultra-low power MSP430F2013 microcontroller.

Software Listing

```
//*****
// MSP430F2013 Flower Power
//
// Description: Second counter using watchdog as
// an interval timer. Ultra-low frequency
// ~ 1.5kHz, ultra-low power in active mode and
// LPM3 mode. ACLK = VLO, MCLK = VLO/8 ~1.5kHz,
// SMCLK = n/a
//
//
//               MSP430F2013
//
//      | | | | |
//      | | | | |
//      --| RST      XOUT| -
//
//      a -| P1.0
//      b -| P1.1
//      c -| P1.2
//      d -| P1.3
//      e -| P1.4      P1.7| - BP
//      f -| P1.5      P1.6| - g
//
//      | | | | |
//
// Carlos Cossio
// December 2009
// Built with IAR Embedded Workbench
// Version: 4.20
//*****

#include <msp430x20x3.h>

// LCD Port 1
// |-----|
// | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
// |-----|
// | BP | g | f | e | d | c | b | a |
// |-----|

#define LCD_0      0x3F
#define LCD_1      0x06
#define LCD_2      0x5B
#define LCD_3      0x4F
#define LCD_4      0x66
#define LCD_5      0x6D
#define LCD_6      0x7D
#define LCD_7      0x07
#define LCD_8      0x7F
#define LCD_9      0x6F
#define LCD_BLANK  0x00

void main(void)
{
    unsigned char lcd = 0;    // LCD index

    BCSCTL3 |= LFXT1S_2;      // LFXT1 = VLO
    IFG1 &= ~OFIFG;           // Clear OSCFault
```

```
        // flag
    __bis_SR_register(SCG1 + SCG0);
        // Stop DCO
    BCSCTL2 |= SELM_3 + DIVM_3;
        // MCLK = LFXT1/8

    WDTCTL = WDT_ADLY_250;    // Interval timer
    IE1 |= WDTIE;              // Enable WDT
        // interrupt

    P1DIR = 0xFF;              // All P1.x outputs
    P1OUT = LCD_0;             // Initialize LCD
    P2DIR = 0xFF;              // All P2.x outputs
    P2OUT = 0;                 // All P2.x reset

    while (1) {
        switch (lcd) {
            case 0:
                P1OUT = LCD_0;    // Display 0
                break;
            case 1:
                P1OUT = LCD_1;    // Display 1
                break;
            case 2:
                P1OUT = LCD_2;    // Display 2
                break;
            case 3:
                P1OUT = LCD_3;    // Display 3
                break;
            case 4:
                P1OUT = LCD_4;    // Display 4
                break;
            case 5:
                P1OUT = LCD_5;    // Display 5
                break;
            case 6:
                P1OUT = LCD_6;    // Display 6
                break;
            case 7:
                P1OUT = LCD_7;    // Display 7
                break;
            case 8:
                P1OUT = LCD_8;    // Display 8
                break;
            case 9:
                P1OUT = LCD_9;    // Display 9
                break;
            default:
                P1OUT = LCD_BLANK; // Clear display
                break;
        }

        lcd++;                  // Next number
        lcd %= 10;               // Only from 0 to 9

        __BIS_SR(LPM3_bits + GIE);    // Enter LPM3
    }

#pragma vector=WDT_VECTOR
__interrupt void watchdog_timer (void)
{
    __BIC_SR_IRQ(LPM3_bits);    // Clear LPM3 bits
        // from 0(SR)
}
```

shows the circuit schematic.

Firmware Design

The microcontroller tools used to develop the Flower Power firmware were the IAR Embedded Workbench Kickstart for MSP430 version 4.20 and the Texas Instruments eZ430-F2013 USB stick for debugging and programming the Flash memory. To download a trial

version (limited to 4K code generation), go to <http://focus.ti.com/docs/toolsw/folders/print/iar-kickstart.html>.

All of the software for this project is designed for low power consumption. After the power-on reset, the MSP430F2013 is configured to use the internal VLO. This frequency is divided by eight to get a master clock of about 1.5 kHz, thus reducing the power consumption in active mode. The watchdog is configured as a timer

RESOURCES

*MSP430x20x1, MSP430x20x2, MSP430x20x3
Mixed Signal Microcontroller (Rev. D)*
Texas Instruments, 2007

MSP430x2xx Family User's Guide (Rev. E)
Texas Instruments, 2008

*Ultra-Low Voltage Nanoelectronics Powered Directly and
Solely from a Tree*, Carlton Himes, Eric Carlson, Ryan J.
Ricchiuti, Brian P. Otis, Babak A. Parviz,
IEEE Transactions on Nanotechnology, 2009

AUTHOR'S NOTE

The project described in this article was awarded the third prize in the international MSP430 Ultra-Low Power Design Challenge 2010 sponsored by Texas Instruments. If you'd like to see a video of the winning project, point your browser to www.designmsp430.com/displayVideo.aspx?id=29e378ef-e65b-4e79-8dfa-91dc8e84dbe3.

interval to wake up the microcontroller approximately every second, so most of the microcontroller's time is spent in Low Power Mode 3 (LPM3) which reduces the power consumption even further.

When the MSP430F2013 wakes up, it displays the next counter value from zero to nine in the LCD and goes to sleep again. This process is endless.

Next Steps

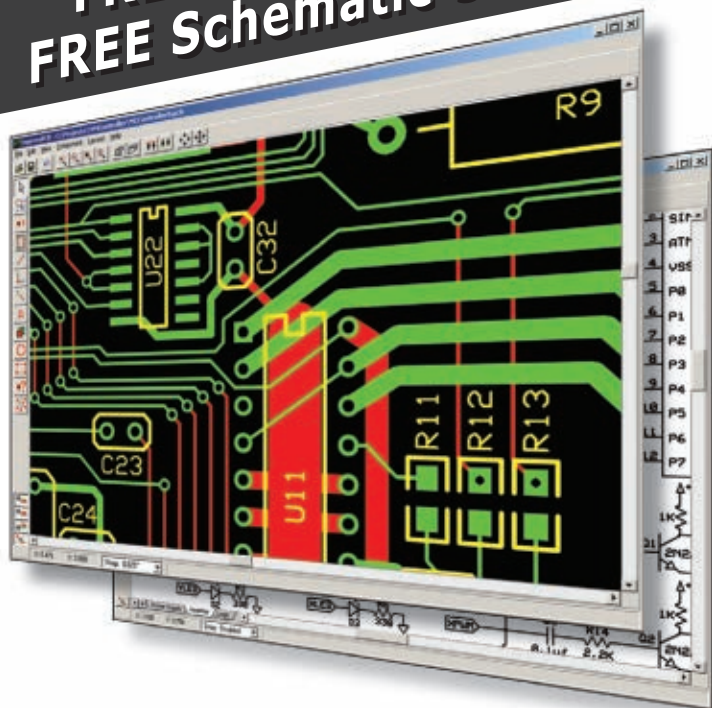
So, now you know how to power an ultra-low power microcontroller, by using the bioelectricity supplied by the plants. Unfortunately, since it's necessary to connect several potted plants together in series to get enough energy to activate the microcontroller, this reduces its practical use on a grand scale. The minimum voltage necessary to activate a transistor in the current CMOS technology is approximately 0.7 volts. However, thanks to new developments in energy harvesting technology, a new generation of oscillator circuits are emerging that are able to run from 0.3 volts.

Since the oscillator is the main building block of a charge pump, it may soon be possible to design a circuit able to store that tiny amount of energy for later use. It would then be possible to power an ultra-low power microcontroller with just one plant instead of several. Now, that would be a novel type of green energy! **NV**

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*I would like to thank Sonia Riveiro
for her assistance with this article.*

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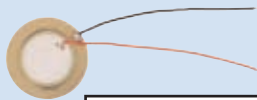
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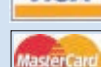
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BUILD A LOW VOLTAGE INSULATION TESTER

BY
DOUGLAS
KRANTZ



Ground faults are a curse to fire alarm systems. Even a small amount of current leaking to ground somewhere in the building can cause an unscheduled fire drill. Worse yet, a second ground fault somewhere else in the building can short out the whole system. That's why all fire alarm systems have ground fault detection circuits, so the attached building wiring can be fixed before there is a fire.

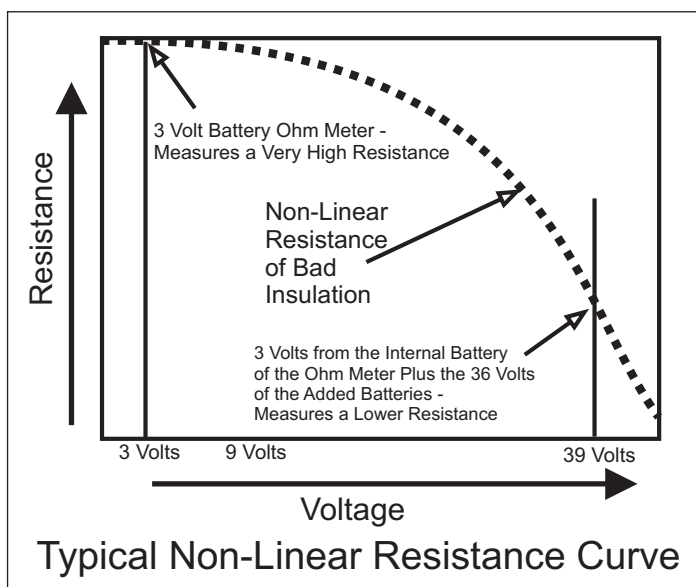
It was perplexing. I was trying to repair a fire alarm system in a school. The air outside was warm and humid, but inside it was air-conditioned. A light on the fire alarm panel indicated "ground fault" somewhere in the wiring in the building, but my digital ohmmeter claimed there wasn't any continuity to ground. How was I going to find this conductive path if my ohmmeter couldn't detect it?

After trying several means of detection, I decided to give my ohmmeter a voltage boost. A couple of 12 volt batteries from my service stock in series with the negative lead of my ohmmeter did that. Now, using about 27 volts of oomph to drive the current of my ohmmeter, it indicated the continuity and I could follow the wiring to find the ground fault. It turned out to be water condensed on a fire alarm pull station in the gym. The humidity from the warm air leaking from the outside through the wall was condensing on the cool air-conditioned switch on the inside. So, why didn't my ohmmeter show any continuity until it got that extra voltage boost from the batteries?

I was dealing with a voltage based non-linear resistance; a resistance that changes value as voltage changes so current doesn't seem to follow Ohm's Law. The resistance of the water condensation was almost infinite for the three volt internal battery of my ohmmeter, but the resistance dropped down to a few thousand ohms when the voltage was increased by the addition of the extra batteries (see **Figure 1**).

Insulation Tester

What I had come up with was not a new invention. It was a test instrument used by electricians called an insulation tester which is an ohmmeter with a high



■ **FIGURE 1.** This chart shows how a non-linear resistance goes down as voltage goes up. The voltage shown here would be the battery voltage of the ohmmeter.

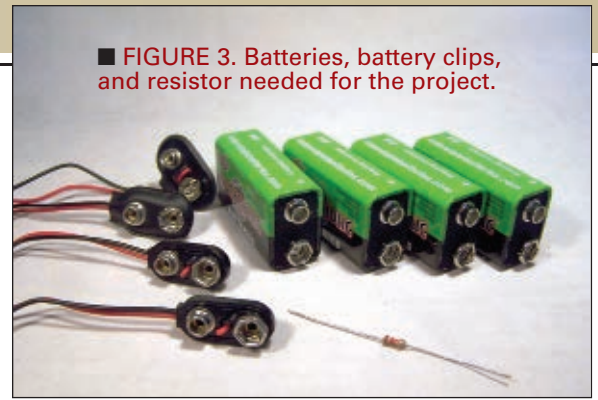
voltage internal battery. In the case of the meter assembly I had come up with, the voltage of all the batteries combined was about 27 volts: the three volts of the battery inside my ohmmeter, plus the 24 volts from the two added 12 volt batteries.



■ FIGURE 2. Inexpensive multimeter.

I really needed to have one of these testers to carry around with me for this kind of troubleshooting, but nothing was available that I could afford. I would have to craft my own. At first, I tried the digital ohmmeter that I normally used for troubleshooting, and put batteries in series with its leads. When I tested the resistance of the same type of trouble I had encountered — water on the surface of the insulator — the numbers on the display kept changing and were hard to read. It turned out that water is transient so the resistance of water keeps changing slightly up and down. I am a troubleshooter and I wanted to concentrate on troubleshooting, not spend time trying to read the meter, so using the digital meter wasn't going to work for me.

Next, I tried an old fashioned analog meter that I had lying around. With the extra batteries, the numbers on the ohm scale weren't accurate anymore, but I could deal with that. At least the needle on the meter didn't move back and forth very much, and I could get a somewhat stable reading. Then, I thought about voltage. In general, fire alarm systems use 24 volts and I needed to test the wiring at voltages that were higher than that. The 36 volts from four nine-volt batteries seemed to be a reasonable voltage, and the four batteries could be strapped to the



■ FIGURE 3. Batteries, battery clips, and resistor needed for the project.

back of the meter, so that's what I used.

The one real worry was that the meter movement would be damaged with excessive current when the leads of the meter — along with the added batteries — were shorted together. To prevent this meltdown, a limiting resistor of a yet unknown value would have to be inserted in series with the added batteries (see **Figures 7 and 8**). Just to make it easier to calibrate the meter, the value of this resistor would have to be chosen so the meter would read zero ohms when the leads were shorted together — like a normal ohmmeter.

Construction

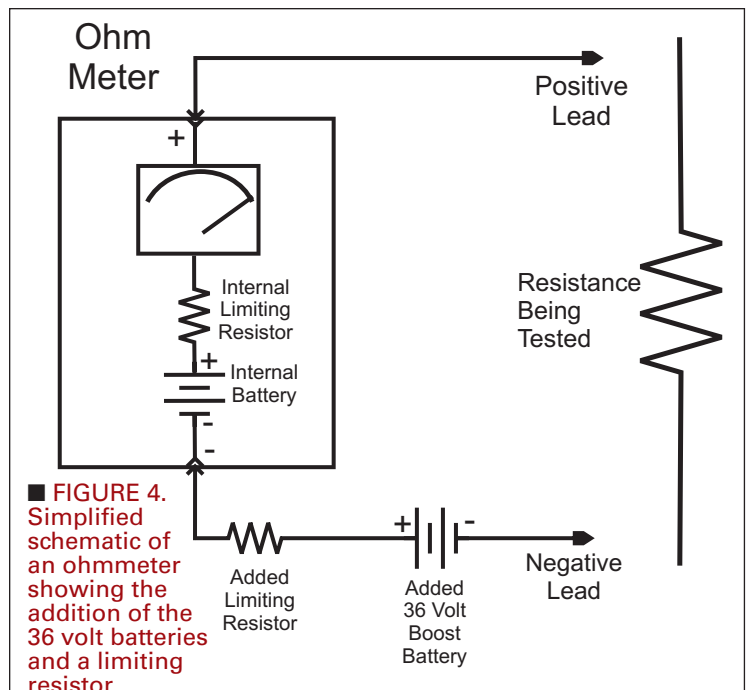
Start out with the battery clips. Solder the battery clip wires red to black so the batteries are in series. Just don't cut the leads short. The extra wire will allow for flexing when the batteries wear out and need to be replaced. Individually tape or heat shrink the connections.

For neatness and organization, tape all four batteries together. Connect the clips to the batteries and use tape to make a pigtail of the loose battery clip leads (see **Figure 7** again).

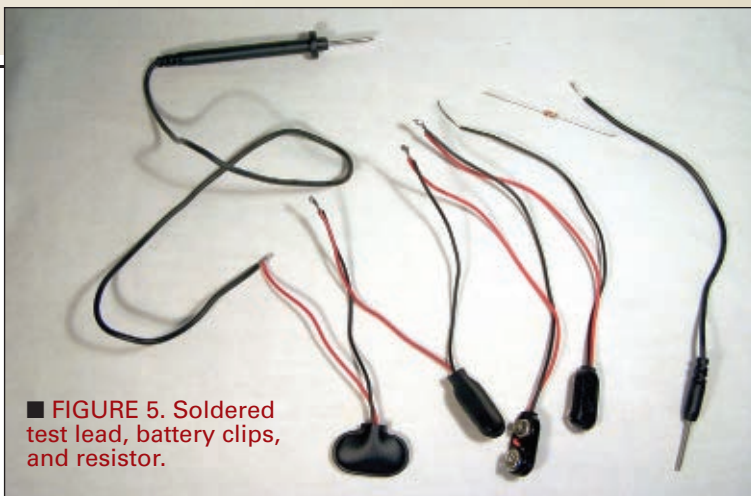
Non-Linear Resistance

Wire insulation doesn't have to be smoking before it's considered bad; it can be slowly breaking down. According to Megger — one of the many manufacturers of insulation testers — causes of insulation breakdown can be electrical stress, mechanical stress, chemical attacks, thermal stress, and environmental contaminations (water condensing on the insulated side of a switch, for instance).

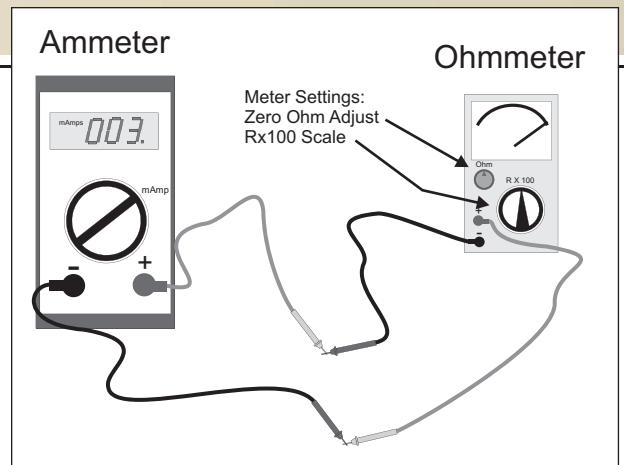
All of these irritants cause voltage-based non-linear resistance — at least at voltages below the smoking stage. The low voltages common to digital ohmmeters show high resistance because the low voltage isn't enough to drive the current through the insulation. The higher voltage in an insulation tester, on the other hand, is enough to drive the current through the partially broken-down insulation, and the measured resistance is lower. (Refer to **Figure 1**.)



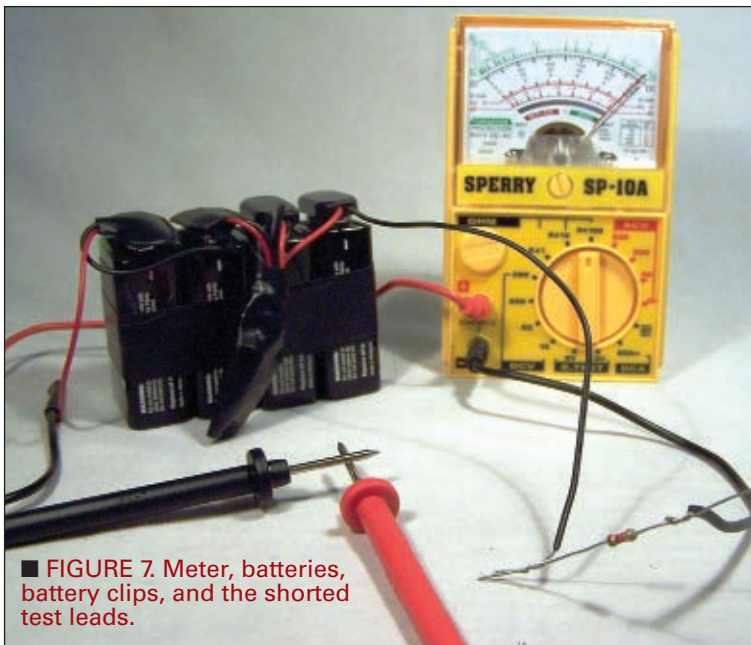
■ FIGURE 4. Simplified schematic of an ohmmeter showing the addition of the 36 volt batteries and a limiting resistor.



■ FIGURE 5. Soldered test lead, battery clips, and resistor.



■ FIGURE 6. Setup to measure the current of the ohmmeter.



■ FIGURE 7. Meter, batteries, battery clips, and the shorted test leads.

Calculating the Value of the Limiting Resistor

The limiting resistor (see **Figure 4**) makes up for the extra voltage of the batteries. That way, when the test

leads are shorted together the ohmmeter will read zero ohms (like a normal ohmmeter). Before proceeding, make sure the ohmmeter is set to the highest ohm scale: RX100 or greater. This is the scale that is going to be used for all future measurements.

There are two methods of determining the value of the limiting resistor. One is to measure the current that the ohmmeter uses to measure zero ohms, and the other is to experiment to find the value. Both methods work.

Current Method

Measure the current generated by the ohmmeter by placing a digital milliamp meter in series (see **Figure 6**). The current measured on the ammeter is the current that the ohmmeter calls zero ohms.

My meter requires approximately 3 milliamps to indicate zero ohms. The Ohm's Law formula ($E / I = R$) works out to be the 36 volt batteries divided by the .003 amps (3 milliamps) generated by the ohmmeter which equals 12,000 ohms for the limiting resistor.

You can confirm this method has found the proper value for the limiting resistor by temporarily inserting the resistor into the meter circuit as shown in **Figures 7 and 8**.

PARTS LIST

QTY	DESCRIPTION/PART NUMBER
1	Meter* – Sperry Instruments HSP10 multimeter from Home Depot or equivalent
1	Resistor Kit** – Digi-Key RS125-ND – 1/4W (.25W), 5%, carbon film, axial lead, 365 pieces (5 ea of 1.0 ~ 1.0M ohms)
4	Nine-volt batteries
4	Clips with leads for the batteries – Digi-Key 377-1549-ND or equivalent
	Electrical tape
	Solder and soldering iron
	Chart paper to make a cross reference table

Cost:

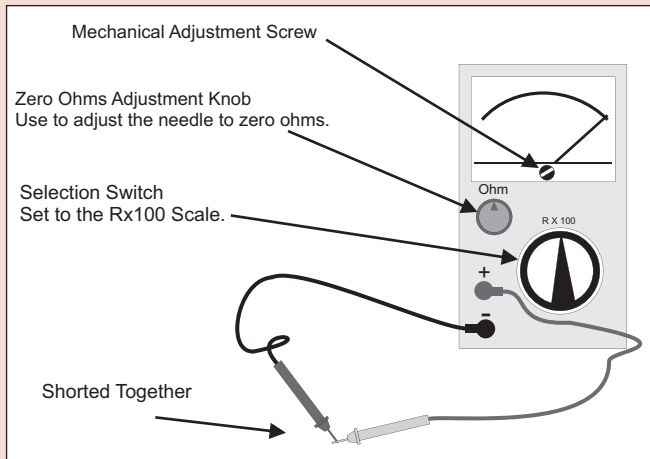
Meter - about \$18
 Mixed Resistor Kit – about \$15
 Batteries, Clips for the Batteries & Miscellaneous – about \$10
 Plus Shipping

*If you have an old analog meter that isn't being used for anything anymore, you can use it instead of purchasing a new one. All the meter needs is its internal battery and its test leads.

** Most of the resistors in the kit won't be used except to calibrate the meter, and the resistors can be reused in future projects. If you have a variety of resistors already, the resistor kit isn't needed.

CALIBRATING A STANDARD OHMMETER

(VOM, OR VOLT-OHM-MILLIAMP METER)



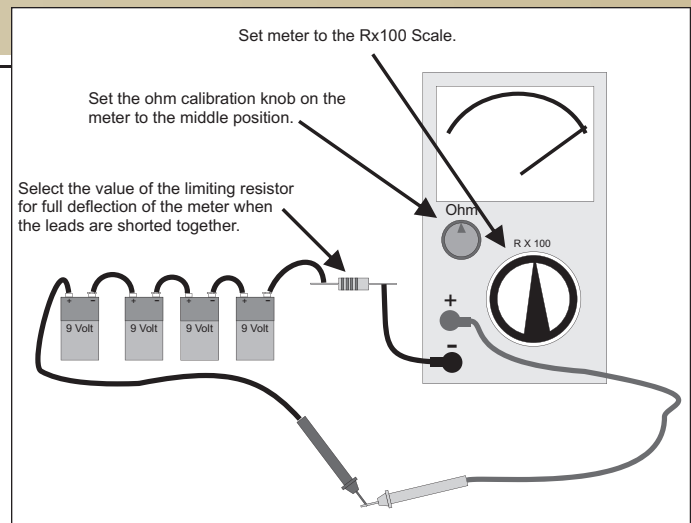
Method for calibrating an analog ohmmeter.

There are only two things to keep in mind when calibrating an analog ohmmeter: the two ends of the scale. The needle points to the left showing infinite ohms (the meter is at rest) when the probes aren't touching anything, or all the way to the right showing zero ohms (maximum measuring current) when the probes are shorted together. When the two ends are calibrated, the numbers in between take care of themselves. Take a look at the figure.

Step one: Place the meter "at rest" by separating the probes. Turn the mechanical adjustment screw either way to adjust the needle to show infinite ohms.

Step two: Set the selection switch to the desired resistance scale: RX1 (resistance times 1), RX10 (times 10), or RX100 (times 100). In the case of the insulation tester, always use the RX100 scale. Now, short the test leads together. Turn the ohms adjustment knob one way or the other until the needle is exactly over the zero ohms on the meter faceplate.

The meter is now calibrated. This calibration adjustment should be done each time the meter is used to measure resistance, or each time the selection switch is set to a different RX position.



■ FIGURE 8. Electro-mechanical layout of all components in the insulation tester.

If the meter can't be zeroed with the ohm adjustment on the meter, the resistance of the limiting resistor may have to be adjusted using the experimental method.

Experimental Method

Center the ohms adjustment knob on the meter. This will allow the knob to be adjusted either way at a later time. Start out with a 20,000 ohm limiting resistor and insert the resistor into the circuit (refer again to Figures 7 and 8). The needle probably won't indicate zero ohms, so try a resistor whose value is a little different. Remember, a lower value of resistance will move the needle to the right.

Look at the ohmmeter again. Keep changing the value of the limiting resistor until the needle is close to zero ohms. This will become the limiting resistor. The ohms adjustment on the meter can be used to touch up the needle to point at zero ohms.

Cutting the Negative Test Lead

Use the black probe wire that comes with the meter; it already has connectors. Cut it about seven inches from the end that goes into the meter, and strip the loose ends (see Figure 5). Seven inches should be enough to secure the soldered end to the batteries and still plug into the meter.

Solder this short lead to one end of the limiting resistor and the other end of the resistor to the positive battery clip lead. Tape or heat shrink the connections.

Solder the stripped end of the long probe wire to the negative battery clip lead (see Figure 5). Tape or heat shrink this connection.

Final Assembly

Tape the limiting resistor and both soldered black test lead ends to the pigtail to give all solder connections mechanical strength. This meter is going to rattle around with the other tools in the tool box, and

Worst Ground Fault

They tried to use a regular ohmmeter to find the ground fault. I watched them. Right after sunset, while there was enough light to see the cityscape and the lit streetlights, I stood on top of the hill overlooking Duluth, MN. They were power company linemen and they had just driven up to a three-phase, 13,800 volt power pole across the street from a TV station which was off the air because of a power blackout. The lineman in the cherry picker used his ohmmeter to check for shorts in the underground line. A nine-volt battery won't find much of a problem on a 13,800 volt power line, and that's what was found — not much of a problem. Well, they put in a new fuse at the top of the pole, turned on the switch, and with the sound of a shotgun and a 15 foot shower of sparks, the fuse blew. All of the city of Duluth went black. There really was a short. A proper insulation tester using a 15,000 volt power source would have detected the problem.

Insulation Meter Cross Reference

Meter Readings	Resistance
.05	100 Ohms
.1	200 Ohms
.25	470 Ohms
.5	1000 Ohms
1	2 kOhms
2.5	4.7 kOhms
5	10 kOhms
10	20 kOhms
25	47 kOhms
50	100 kOhms
100	200 kOhms
250	470 kOhms
500	1 Mohms
Barely moves the meter needle	2 Mohms

This assembly of the batteries and pigtail can be put in a plastic chassis box and then attached to the meter. Personally, I never found a commercial box that was both big enough to house the whole battery assembly and

■ **FIGURE 9.**
Cross reference chart.

the solder connections need to be protected so they do not move and break.

IDEAS FOR THE FUTURE

Switch contacts get dirty and one way of making sure dirty contacts don't cause a problem is to solder the switch contacts. Of course, this will dedicate the meter and prevent it from ever being used for anything else.

Replacing the internal batteries when the case is taped together can be a real pain. One idea is to remove the battery and replace it with a soldered-in jumper. Then, there is no internal battery to replace.

For those who have real energy, the meter can be backwards engineered and the internal resistors recalculated so the meter can be used on all scales (RX1, RX10, RX100). The resistance scale on the face of the meter will still be off so a cross reference table will be needed, but the meter will be a little more versatile.

small enough to fit on the back of the meter, so I just used copious amounts of electrical tape to attach the assembly to the back of the meter.

Ohmmeter

Ohmmeters use Ohm's Law (Resistance = Voltage ÷ Amperage) to figure out the resistance of the device being measured. The voltage is provided by the meter's internal battery and remains relatively constant. The amperage is the current through the device being tested; in this case, insulation on wire.

On an analog meter (a meter that has a mechanical meter movement), the needle actually shows the amount of current through the device. It moves to the right as the resistance goes down and the current goes up. When the

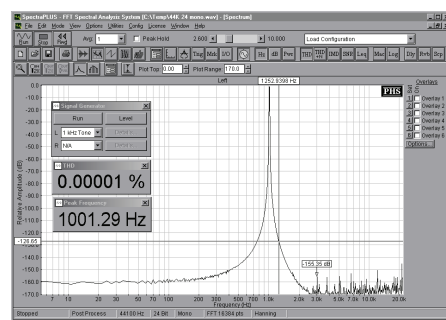
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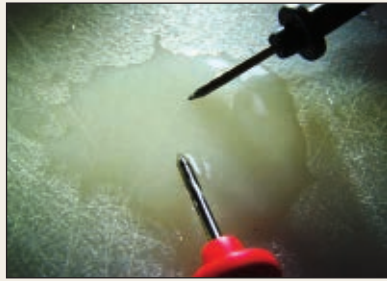
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Try This At Home

Will the insulation tester detect problems that a regular digital ohmmeter won't? Find out! Try this on one type of insulation problem: water on the wiring.

Spill a little tap water on a clean counter. The puddle should be about one or two inches in diameter. Just don't add any salt or other contaminants to the water. Measure the resistance of the water using a regular digital ohmmeter, keeping the tips of the probes at least 1/2 inch apart as shown in **Figure A**. Write down the resistance indicated on the ohmmeter. Some digital ohmmeters will measure infinite resistance, and if that is measured, that's what should be written down. As a control, find a resistor of about the same value and measure its resistance. Write down that measurement.

Use the insulation tester to measure the same water. Look up the actual resistance on the cross reference table and write down that resistance. The resistance measured



■ **FIGURE A.** Testing the resistance of a puddle of water. The probes here are about 1/2 inch apart and both of them are in the water.

by the digital ohmmeter and the resistance measured by the insulation tester will be quite different.

To check the accuracy of the insulation tester, use it to measure the resistance of the control resistor. (Make sure to keep your fingers off the leads because they will corrupt the readings.) Look up the true resistance of the resistor on the cross reference table.

The measured resistance of the control resistor should be about the same whether the digital ohmmeter is used or the insulation tester is used. Water, on the other hand, has a voltage-based, non-linear resistance. That helps

explain why the insulation tester — with its high voltage battery — detects a definite problem the water on the insulation, while the digital ohmmeter — with its low voltage battery — shows uncertain readings.

If you really want to have fun with this experiment, try shaking a bunch of salt into the puddle of water and measure the water's resistance again with both meters.

resistance reaches zero ohms (the leads shorted together), the current through the meter is at maximum and the needle is all the way to the right. The numbers on the face of the meter make up a conversion table or cross reference table. It converts the current flowing through the device being measured to the resistance of that device. The numbers on the meter's face are then multiplied by the switch setting of RX1, RX10, or RX100 to calculate the total resistance being measured. A digital ohmmeter does

this cross reference automatically; it converts the test current to resistance to give a direct reading on the display.

Creating a Cross Reference Table

With the added batteries and limiting resistor, the numbers on the face of the meter are no longer factory calibrated. For instance, a resistor under test with my ohmmeter may show 25 on the ohms scale. Normally, this

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number would be multiplied by 100 (RX100) to represent 2,500 ohms. My meter has been modified, so using a cross reference table I see that this resistor is a 47,000 ohm resistor.

The question: "How do I obtain this cross reference table?" The answer: "Make it." Each meter is different, so each meter requires its own chart.

To make the chart, choose the values for resistors shown in **Figure 9**. Then, measure the resistors one at a time, making sure to zero the meter between each measurement. Write down the meter reading for each

resistor next to its value. When the table is filled out, it is ready to be used as a cross reference chart.

Just remember to use the RX100 setting on the meter for all resistance measurements. Also, keep in mind that the meter is now applying over 36 volts to whatever is being tested, so make sure there aren't any delicate electronics in the circuit being measured.

Conclusion

This modified meter is no longer a regular ohmmeter;

it's an "insulation tester." With a meter like this, I have found wires where the insulation was partially rubbed off; I found a leaky lightning arrestor; I found wire to wire faults inside walls; and I found many instances of water damage. Any fault or conduction that a fire alarm panel detects with its ground fault detection circuit I can now find with this insulation tester.

My old inexpensive analog meter has a use again, and I can easily find wiring faults in a building that can't be found with a regular ohmmeter.

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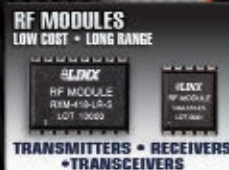
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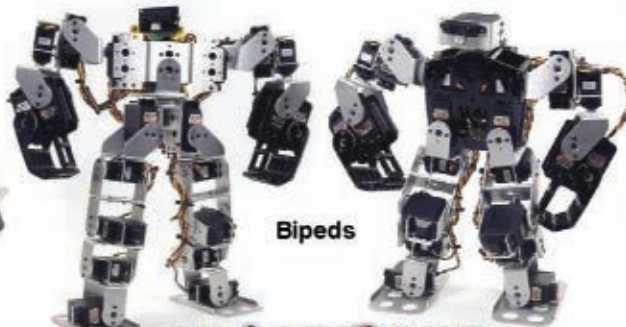
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PROTOTYPE THIS

With Joe Grand

Virtual Sea Adventure



Joe experiencing the Virtual Sea Adventure – fully submerged in water and controlling the ROV using magnetic position sensors.

PrototypeThis, an engineering entertainment program on Discovery Channel, offered a view into the real-life process of designing and building unique prototypes. In this 13 episode series which was filmed over the course of 18 months and aired starting in October 2008, we set out to tackle the problems of today by creating crazy, one-of-a-kind inventions of tomorrow. I was the team's electrical engineer and hardware hacker, and shared the screen with Zoz Brooks, a roboticist and software designer specializing in human-machine interaction; Mike North, a material scientist and mechanical engineer; and Terry Sandin, a special effects veteran. We were challenged to build things that had never been done before, looked cool on TV, and could be completed within the extremely tight financial and time constraints of television production. It was a fantastic adventure and great experience to say the least!

This quarterly series of articles will cover the electronic aspects of some of my favorite projects from the show. My hope is that you will be inspired, learn something new, or use my work as a building block for your own open source project. Let's begin!

What the Heck is a Virtual Sea Adventure!?

The Virtual Sea Adventure episode followed the process of our most arcane invention in which we set out to build a remotely-operated virtual scuba diving experience. The goal was to allow a scuba diver in San Francisco, for example, to feel like they are swimming with the sharks in the Bahamas. We used an off-the-shelf SeaBotix (www.seabotix.com) LBV150SE ROV (Remotely Operated Vehicle) controlled by the "player" using custom control circuitry. The ROV would send back high-definition video that would be projected onto an underwater display located directly in front of the player. All player-to-ROV and ROV-to-player communications would take place over a network. In theory, the player and ROV could be located in two completely disparate locations anywhere in the world. Sound crazy? It was. And, we only had a few weeks to design, build, and test the whole thing!

This article focuses only on the magnetic position sensor circuitry used by the player to control the ROV. I felt that it was one of the cooler aspects of the build and something that could be ported to lots of other hobbyist and robotics applications. For those who want to dive deeper (no pun intended!), the technical documentation I

Joe Grand is an electrical engineer, hardware hacker, and president of Grand Idea Studio, Inc. (www.grandideastudio.com), where he specializes in the invention, design, and licensing of consumer products and modules for electronics hobbyists. He can be reached at joe@grandideastudio.com.

created for the entire build — including schematics, source code, and development notes — is available on my website (www.grandideastudio.com/portfolio/pt-virtual-sea-adventure/).

Introducing the Melexis MLX90333

A main facet of this project was for the player to be able to control the ROV while being underwater. As such, we had a challenge to make the controls waterproof. Typical mechanical joysticks or controllers were out of the question, as they are susceptible to damage due to water leakage or corrosion. Off-the-shelf industrial, waterproof controls were too bulky and expensive for our particular design. So, I decided to experiment with a magnetic position sensor: the Melexis MLX90333 3-D Joystick Position Sensor (www.melexis.com/Sensor_ICs_Hall_effect/Triaxis_Hall_ICs/MLX90333_648.aspx).

The sensor is designed to detect any magnet moving in its surrounding area and is specifically intended for non-contacting joystick implementations. In its default configuration, the MLX90333 outputs analog voltages depending on the magnet's position. My thought was that I could attach magnets to the player's left and right thumbs and, by simply moving his thumbs over the sensors, the player would be able to drive the ROV (after some processing of the analog voltages into the proper control signals, of course).

Magnet Controlled Etch A Sketch

During each episode of *Prototype This*, we interspersed short and quirky segments called "podcasts" (because their style was based on video podcasts I had released on the web prior to filming *Prototype This*) to help explain complicated or technical components of the build in a fun way. One podcast segment we created was to show off the magnetic position sensor and demonstrate the feasibility of using it as a joystick control for the ROV. For this simple and straightforward example, I used the outputs of a single MLX90333 to control the direction and speed of two continuous rotation servo motors attached to the X and Y axes of a classic Etch A Sketch® toy. The further away the magnet was from the center of the sensor, the faster the associated servo would move.

The hardware used in this demonstration is a subset of the full schematic (which represents our complete Virtual Sea Adventure system) and can easily be built on a prototype board (I used a Parallax Board-of-Education). Since the BASIC Stamp 2 doesn't have its own built-in A/D capabilities, I used two National Semiconductor ADC0831

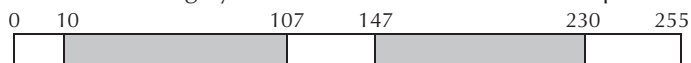


SeaBotix LBV150SE ROV with control unit showing video received from its HD camera.

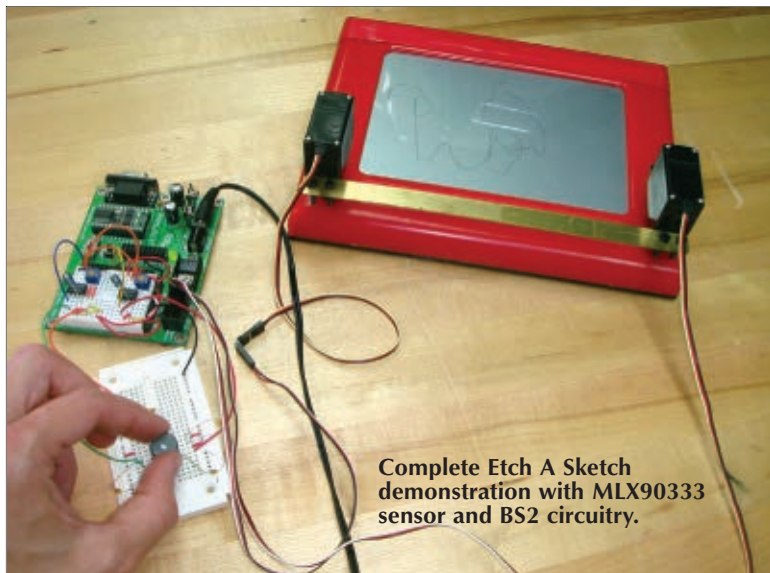
(www.national.com/mpf/DC/ADC0831.html) eight-bit successive approximation A/Ds to convert the two analog voltages output from the single MLX90333. The results are transferred to the host via a simple synchronous serial interface. The final design of my Virtual Sea Adventure system used a four-channel version of the ADC0831 (the ADC0834) and two MLX90333 sensors, as I had both left and right thumbs to contend with. Since the full source code for this demonstration is available on my website and in the interest of space, only one channel (left/right) is discussed here, but the code is essentially the same for the second channel (up/down). First, I simply read the output of the MLX90333 with the ADC0831:

```
LOW AdcCS_OUT1
SHIFTIN AdcDta, AdcClk, MSBPOST, [MLX_OUT1\9]
' get the voltage
HIGH AdcCS_OUT1
DEBUG " OUT1: ", DEC3 MLX_OUT1
```

The graphic below illustrates the range of possible values (0-255) returned from the A/D. Values within the gray areas will be scaled and used to move the servo. Values outside of the gray areas will cause the servo to stop:



Joe explaining the concept of a magnetic position sensor.



Complete Etch A Sketch demonstration with MLX90333 sensor and BS2 circuitry.

In my experiments with the sensor, I noticed that values less than IDLE_LOW or greater than IDLE_HIGH usually meant there was no magnet detected. So, I'd check the returned value (MLX_OUT1) to make sure it was within range. I also checked to make sure that MLX_OUT1 was outside of my pre-defined deadband (set by DEADBAND_LOW and DEADBAND_HIGH) which was put in place to prevent jitter around the center position of the sensor.

```
IF (MLX_OUT1 < IDLE_LOW OR MLX_OUT1 >
IDLE_HIGH OR (MLX_OUT1 > DEADBAND_LOW AND
MLX_OUT1 < DEADBAND_HIGH)) THEN
    result_x = 750 ` stop moving servo
```

Next, if the value of MLX_OUT1 is within the valid (gray) area, we continue with the rest of the IF...ELSE statement:

```
ELSE ` there is a magnet in range, so let's
scale it and set the servo speed
IF (MLX_OUT1 >= IDLE_LOW AND MLX_OUT1
<= DEADBAND_LOW) THEN
    DEBUG " X: CW"
    result_x = ((MLX_OUT1 - IDLE_LOW) / 6)
+ 730
ELSEIF (MLX_OUT1 >= DEADBAND_HIGH AND
MLX_OUT1 <= IDLE_HIGH) THEN
    DEBUG " X: CCW"
    result_x = ((MLX_OUT1 - DEADBAND_HIGH)
/ 6) + 754
ENDIF
DEBUG " SERVO_X: ", DEC result_x, CR
ENDIF
```

The value of MLX_OUT1 determines the speed and direction that the servo will move (for example, moving the magnet left over the sensor would cause the servo to rotate counter-clockwise as seen from the back of the servo). Simple scaling is performed to fit MLX_OUT1 into a valid value to be used with the standard BS2 PULSOUT command to drive the servo. On the BS2, the output pulse generated with the PULSOUT command is twice the value of result_x.

```
PULSOUT Servo_X, result_x
```

For example, if result_x is set to 750, the output pulse is 1.5 ms (1,500 μ s) which will stop the movement of a continuous rotation digital servo. A 1 ms pulse represents full speed in one direction and a 2 ms pulse represents full speed in the other direction. Any pulse in between will correspond to a speed between full on and full off.

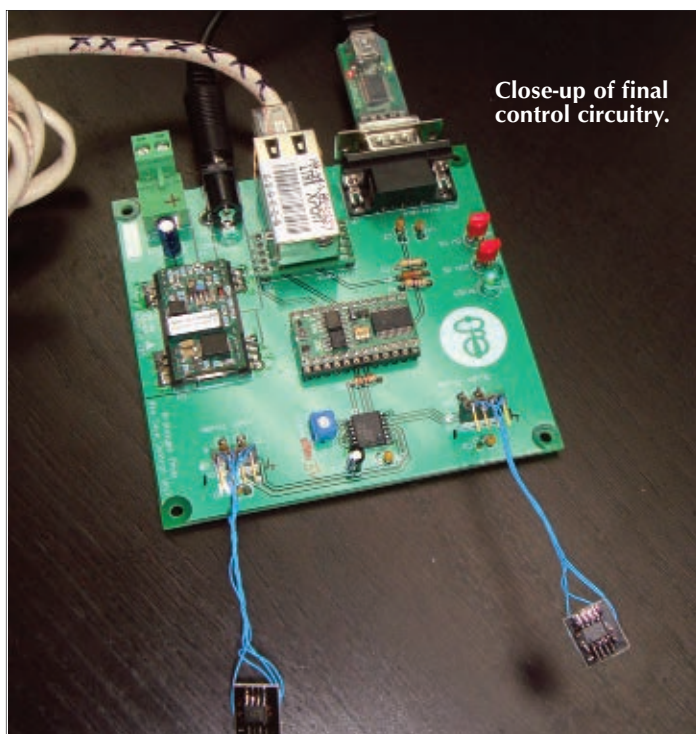
That's it! The code repeats in a loop, continuously checking the output value of the MLX90333 and moving the servo accordingly.

Swimming with the Fishes

The final end-to-end system used the MLX90333

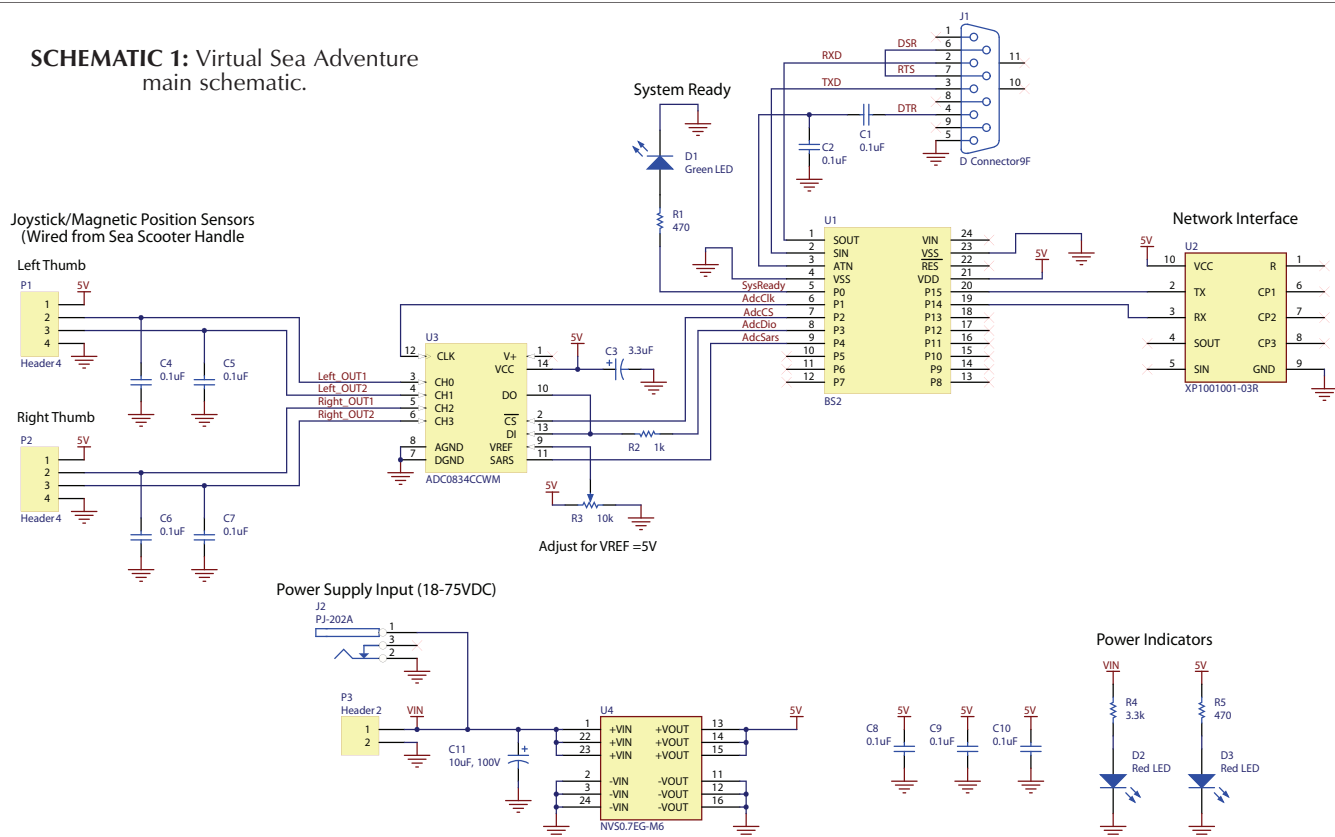


Waterproof thumb control housing with integrated MLX90333 sensor.



Close-up of final control circuitry.

SCHEMATIC 1: Virtual Sea Adventure main schematic.



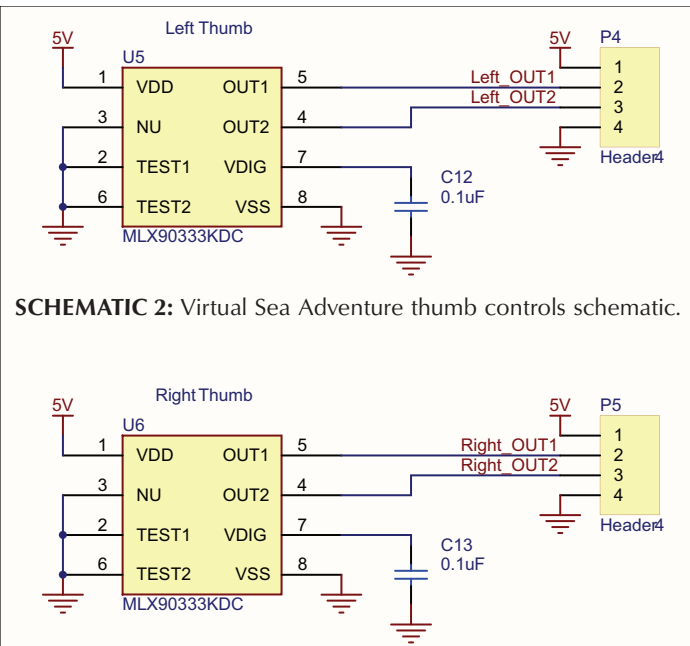
sensors to determine positions (in two axes) of the left and right thumbs on the handle of a modified XRACER Sea Scooter (which was gutted and replaced with our custom circuitry). The data is formed into a command packet per the SeaBotix LBV150SE ROV specifications and transmitted over the network in a UDP broadcast packet using a Lantronix XPORT module. A Lantronix XPORT Test Board receives the packet on the other end of the network and outputs the data in RS-232 (9600 baud) to the actual ROV which interprets the packet and moves accordingly.

Going Deep

Though not without its trials and tribulations (you'll have to watch the episode for all the details), our build was a complete success. We held the finale at Six Flags Discovery Kingdom in Vallejo, CA. I was chosen as the player and was submerged in a tank normally reserved for dolphins (who graciously moved to a different location for our filming).

One thousand feet away across the theme park was Discovery Kingdom's Shark Experience, most famous for being featured in the movie *50 First Dates* with Adam Sandler and Drew Barrymore. The ROV was plopped into the water along with Zoz (who helped keep the ROV's tether from getting snagged on coral or stuck in the sand) and a shark trainer (who helped protect Zoz).

None of us had any idea how well the illusion would work being fully clad in SCUBA gear, staring at a domed projector monitor under the water, and controlling the ROV with magnets inserted into the thumbs of diving gloves. But, it worked, and I actually felt like I was in the shark tank swimming with the fishes. It truly was a virtual sea adventure! **NV**



SCHEMATIC 2: Virtual Sea Adventure thumb controls schematic.



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This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, & much more. Kit supplied with PCB, & all electronic components.

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- Control range: approx. 0 - 90 %
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by Joe Pardue

AVR Memory Part 4: Writing to AVR Flash

Recap

Last month, we continued our AVR Memory series and discussed reading the program memory in Flash. We learned how to store constants in Flash to avoid unnecessarily cluttering SRAM and we learned how to read data from Flash. This month, we will learn how to write to Flash using C functions from avrlibc. This will be the basis for our final article in the memory series (next month) where we apply what we've learned to building a bootloader.

My Big Fat BSOD

FYI, I got a Vista BSOD (Blue Screen Of Death) while testing this code. **Figure 2** shows the message I got after I rebooted. You'll note that it gave me the option to either cancel or check later, but no option to check now. Ah, Vista ... you gotta love it.

I think my big fat BSOD was because an error in the AVR code caused the serial port to be blasted with data while I was using Bray's Terminal. Well, at least Bray's was being blasted with data when I got the BSOD. Everything recovered okay and I fixed the code to be blast free. But you never know ...

Writing To Flash

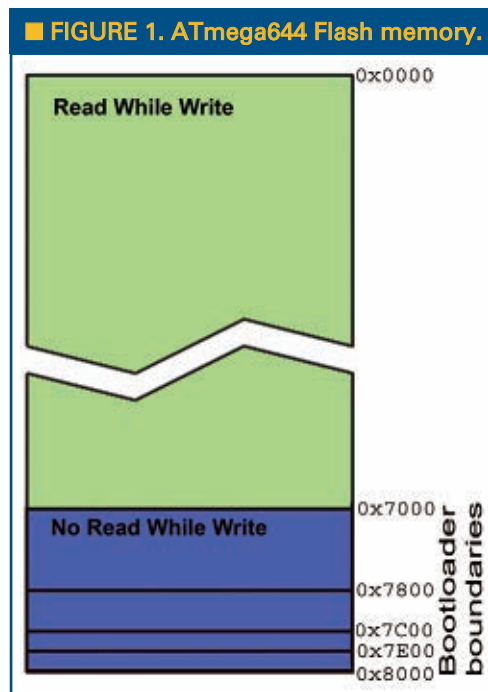
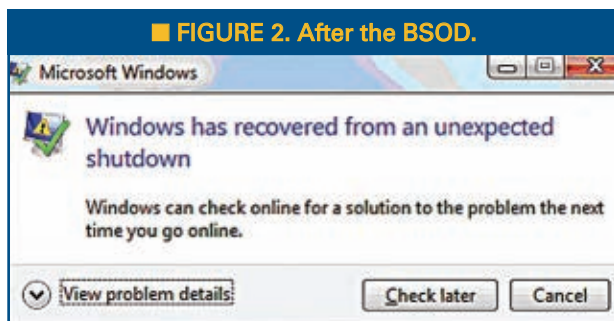
Flash is easy to read, but hard to write.

In previous articles, we've seen that the AVR uses three main types of memory: SRAM, EEPROM, and Flash. We learned that SRAM is the most expensive and only used to store data that changes a lot when the CPU is running; that EEPROM is cheaper and is useful for storing byte-sized constants that change occasionally; and finally, that Flash is

cheapest of all and is used to store the program code that rarely changes. Flash and EEPROM use similar technology, but EEPROM can be programmed in individual bytes while Flash is programmed in pages. This reduces the circuitry necessary to program Flash, thus making it cheaper. Flash page size varies depending on the particular AVR device.

Flash is addressed by words, not bytes.

One additional noteworthy feature of Flash versus the other memory is that Flash stores data as 16-bit words, meaning that eight-bit byte data is stored in either the high or low part of a word. For me, this creates a conceptual problem because for the AVR — which is an eight-bit system — we think in terms of bytes. So, why is the memory now considered in words? Well, that is because the Flash memory itself is a peripheral (something outside the CPU) that is erased and written to in pages with word-sized boundaries. I find this confusing and suggest that you just do what I do: Try to remember that when the CPU is reading Flash memory, it is doing it in bytes but that when we are talking about actually erasing or writing to the Flash memory, we are doing that





in page-sized chunks that are defined in words.

The Arduino (ATmega328p) and the Butterfly (ATmega169) both have pages of 64 words, while the BeAVR40 (ATmega644p) has 128 word pages. Later when we look at boot section addresses, we might notice things like the ATmega644 boot section that begins at 0x7E00, and if we translate that into decimal we might wonder why the bootsection begins at 32256 when we are using a 65535 (64K bytes) memory. The answer is, of course, that we are actually using a 32K word memory and that the boot section is a word address that corresponds to a byte address of 0xFC00 (64512). It can sometimes be confusing whether you are talking about words or bytes in Flash memory, so pay attention.

How Flash is written.

When we write to Flash on the ATmega644, we first fill a SRAM temporary buffer page with 128 words and then let the Flash circuitry write that whole page to Flash. Even if all we wanted to do in Flash is change a single byte, we have to find what page it is in, copy that whole page of 256 bytes (128 words) to SRAM, and then wait while the SRAM gets written to Flash. As we've said before, you *can* write to Flash but you *can* also wear it out. So, it isn't something we want to do a lot. We don't use it to store frequently changing data, but only to store occasionally changing things like the program code itself. Most microcontrollers only have the program written once and they run it to the end of time. We, of course, are learning about these things, so will write the program code many times to both learn new stuff and to correct the inevitable mistakes we make.

Would you change code while it is running? (Hint: NO!)

A computer loads a sequence of instructions from the program memory and performs operations based on that code. We assume there is some logic to the design of that sequence so that, for instance, if we add two numbers then the result is used for some later instruction in the sequence. But what if we could change the program sequence while it is running? We might get lucky and change a section that won't be used for a while, but then we might get unlucky and change something that is being used right now. Since that is a risk we don't want to take, we try to assure that the computer won't be running code that is in the process of being changed. We don't want to be reading code while writing to it.

As we introduced in Workshop 22, bootloaders write code to program memory. A bootloader is a module of code that writes code while it is running. You see the potential

problem here? You've got to have a mechanism that prevents you from writing over code you are running. The AVR has special features that make it easier to safely use bootloaders. One of these is to divide the program memory into two sections: a RRW (Read While Write) and NRWW (No Read While Write) section as shown in **Figure 1**. This allows us to designate a section of memory that will not allow the CPU to read the program memory while writing to program memory. This assures that code running in the NRWW section won't overwrite itself. [We use an external ISP programmer to write to the NRWW section which is done without the CPU running.] As you can see in **Figure 1**, the NRWW section is divided into subsections that mark boundaries that you can set for your bootloader. These boundaries are set by fuses that tell the AVR to run code beginning at that indicated address when coming out of reset. In our Flash writing example [see **Figure 3**], we will use the smallest section available that begins at address 0x7E00 [remember that Flash is measured in words]. This means we have 512 words or 1,024 bytes to store in our bootloader. We will learn how to use this to write data to Flash and next month we will apply what we learn to developing a bootloader.

When an NRWW section is being written to, the CPU is stopped to make sure it doesn't try to run a page of code that is in the midst of being changed. We can continue to execute code in the NRWW section while parts of that section are being written to. This allows our application to continue to run critical code while the rest of the program is being updated. This is an advanced topic that we won't look at further here.

Preventing Flash Corruption.

You should never initiate a Flash write if there is a chance that you'll run out of power in the midst of it. This could corrupt that page of Flash and when the power is restored, the program may be corrupted. One way to deal with this is to enable the internal BOD (Brown-Out Detector) to prevent the CPU from operating below a certain voltage. We will do this by setting the BODLEVEL fuse to "Brown-out detection at VCC=2.7V." We'll see how to set fuses in a few minutes.

Flash Read/Write Functions From AVRLIBC

Writing to Flash requires using the assembly instruction SPM, but we are writing our code in C so we will use some C library functions and let them handle the low level stuff. Avrlibc is included in your WinAVR installation. You can find the manual for it under the WinAVR directory doc\avrlibc\avr-libc-user-manual.pdf. This library provides a lot of useful tools and we will use some of the bootloader support utilities available to us by including `<avr/boot.h>` in our program. We use the following functions:

boot_page_erase(address); Determines the Flash page that contains the 'address' and erases that page.

boot_spm_busy_wait(); Checks to see if the SPM

■ FIGURE 3. ATmega644 boot size.

Boot Memory Sections				
BOOTSZ1	BOOTSZ0	Boot Size	Pages	Application Flash Section
1	1	512 words	4	0x0000 - 0x7DFF
1	0	1024 words	8	0x0000 - 0x7BFF
0	1	2048 words	16	0x0000 - 0x77FF
0	0	4096 words	32	0x0000 - 0x6FFF

instruction is busy. This sits around blocking further action until the Flash has finished writing.

boot_page_fill(address,tempWord); Used to fill the temporary page buffer. It is odd in that it uses a byte address but writes a word, so you have to load the high and low bytes of the tempWord and then add two to the address to load the next word. The algorithm is shown in the blockFlashLoad function we'll discuss in a moment.

boot_page_write(address); Writes the temporary page buffer to the Flash page containing the address.

boot_rww_enable(); Enables the read while write section after you are finished with your writing.

We will demonstrate how to use these function in a program that lets us write data to Flash.

SmileyFlashTest.c

Our demonstration program — SmileyFlashTest.c [available in Workshop26.zip from *Nuts & Volts*] is built on top of last month's pgmtest.c program and contains some communication and logic code that were discussed in that workshop. For this discussion, we will focus on using the avrlibc boot functions to write Flash data.

We will test these concepts by letting the user write 16 bytes to address 0x2000. There are two versions of this write: one will write the sequence 0 to 15 and the other will write the sequence 15 to 0. We write the first sequence by using Bray's Terminal to send 'w' and the second sequence by sending 'W.' We test that the write has actually occurred by reading 16 bytes from address 0x2000 by sending 'r.'

The action we are interested in occurs in the blockFlashLoad function that follows:

```
void blockFlashLoad(uint16_t size)
{
    // address is global and set elsewhere
    uint16_t tempAddress = address;
    uint16_t i,tempWord;

    // Perform page erase
    boot_page_erase(address);

    // Wait until the memory is erased
    boot_spm_busy_wait();

    // fill the flash page buffer with the data
    for(i = 0; i < size; i+=2)
    {
        // load the little end byte from the word
        tempWord = pageBuffer[i];

        // load the big end byte
        tempWord += (pageBuffer[i+1] << 8);

        // put the word into the page butter
        boot_page_fill(address,tempWord);

        // increment the word address
        address = address + 2;
    }

    // write the page to flash
```

```
boot_page_write(tempAddress);

// wait until finished writing
boot_spm_busy_wait();

// Re-enable the RWW section
boot_rww_enable();

// send ! to shown you are done
sendByte('!');
}
```

We see from this that we first erase the Flash page, wait until the erase is finished, load our data into a page buffer, write that page buffer, wait until the write is finished, re-enable the read while write section, then finally send an '!' because we are amazed that this actually worked.

One source for multiple AVR's.

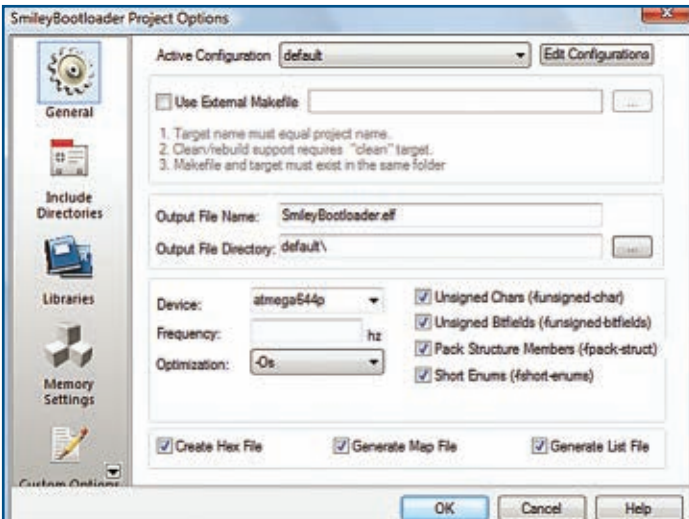
At this point, we are going to go off on a tangent unrelated to memory but important for our current and future Workshops, and that is the concept of creating one source code module that can be easily compiled for several different AVR's. It is common when writing software to want to run it on different devices. For instance, I might want to provide the reader with the opportunity to run the test code on an AVR Butterfly [ATmega169], or an Arduino board [ATmega328], or the BeAVR40 [ATmega644 discussed in Smiley's Workshop 22: Busy as a BeAVR]. I could produce three different source code files for this and that would probably be the easiest for the reader to use. But for me, it would be a lot harder since most of the code would be common for all three sets and I'd have to make sure that I made every little change or error correction to all three files.

Many implementations of C use a preprocessor that is run before the compilation. We can include macros using the #define statement that tells the compiler to substitute one set of text for another. We can also have conditional inclusion using the #if preprocessor statements (remember this isn't the C program '#' or 'if' — it is a preprocessor '#if'). We will use the #define and #if preprocessor statements to generate code that can be made to compile for one of our three systems, depending on which system is defined. Near the top of the SmileyFlashTest.h header file, you will see:

```
//#define Butterfly // ATmega169
//#define Arduino // ATmega328
#define BeAVR40 // ATmega644
```

You can get the compiler to generate code for your particular system by removing the // comment directive from the #define while making sure all the remaining defines have // in front of them. In the case above, the ATmega644 is selected. Later in the code, we will use the preprocessor #if directive to select the code for the indicated device as we see in the following:

```
// Constants used to calculate the register
// settings for each device baudrate
#if defined(Butterfly)
#include <avr/interrupt.h>
#define F_CPU 8000000
#define BAUD 19200
```



■ FIGURE 4. Project Options - General.

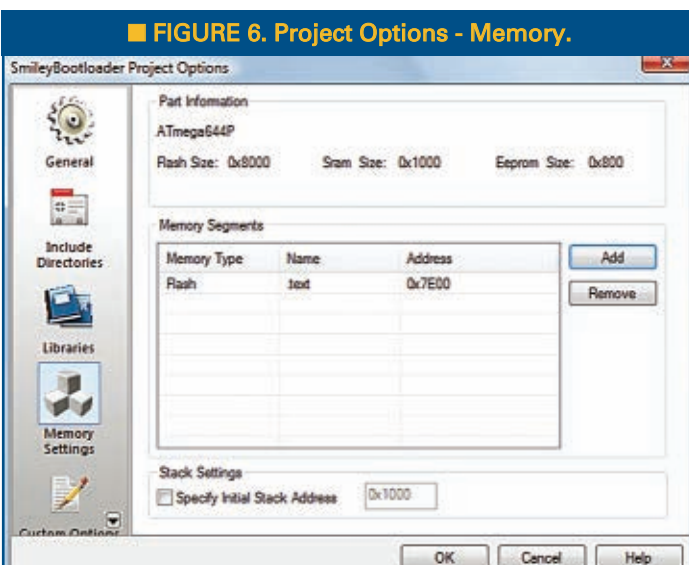
```
#elif (defined(Arduino) || defined(BeAVR40))
#define F_CPU 16000000L
#define BAUD 57600
#else
#error "F_CPU and BAUD undefined"
#endif
```

These #if conditions set the bootloader baud rate. If none of the devices are defined, it causes the compiler to generate the following error:

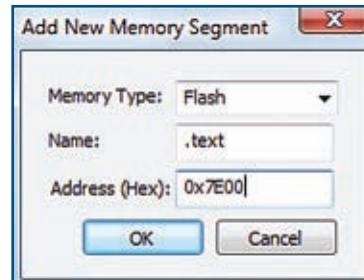
```
../SmileyFlashTest.h:105:3: error: #error "F_CPU
and BAUD undefined"
```

The F_CPU and BAUD are used to calculate the baudrate in the USARTInit() function in the source code. This function also uses the #if #elif preprocessor directives to select and set other device-specific USART registers.

IMHO you have to be careful how you use the preprocessor or you can get nearly unreadable source code. I have at times had to go through other people's code and delete all the conditional statements that



■ FIGURE 6. Project Options - Memory.



■ FIGURE 5. Add New Memory Segment.

weren't relevant to the device I was using just so I could follow the logic of their code. The Arduino bootloader [<http://code.google.com/p/arduino/source/browse/#svn/trunk/hardware/bootloaders>] is a bit like this IMHO, though not nearly as bad as some I've come across.

Since I plan to keep future Workshops to the three devices listed, we can hope that the code won't get too cluttered.

Using AVRStudio To Compile And Load FlashWriter

AVRStudio now has features that allow you to compile programs without having to mess with a Makefile. We will set some Project Options and will make sure that the correct fuses are set in our AVR Programmer.

Settings for Project Options.

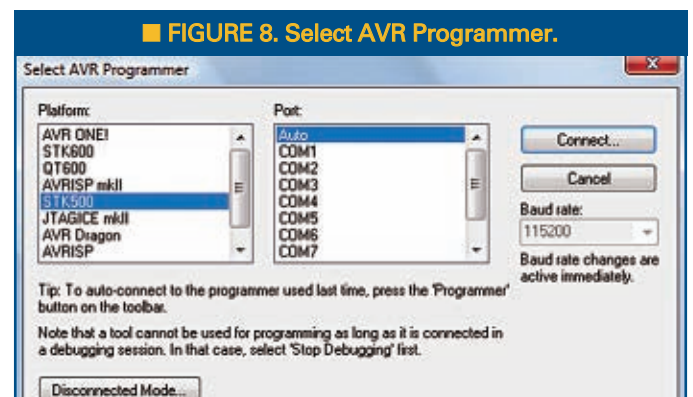
In the AVRStudio Project menu, open Configuration Options. In **Figure 4**, we see the General page set for the ATmega644p used in the BeAVR40.

Setting the Memory Settings.

Open the Memory Settings panel and click on the Add button. In the Add New Memory Segment dialog shown in **Figure 5**, select Flash, type in the name ".text" making sure to include the preceding dot in .text, then set the address to



■ FIGURE 7. Display Connect Dialog.



■ FIGURE 8. Select AVR Programmer.

0x7E00 (the beginning of our bootloader memory segment). The results should be as shown in **Figure 6**.

Settings for fuses.

We want this code to write to Flash so it must reside in the bootloader section. We want to tell the AVR that it should run this code when the device comes out of reset, and we should tell it where the code is located. Click the Display the 'Connect Dialog' button as shown in **Figure 7**. This will open the dialog

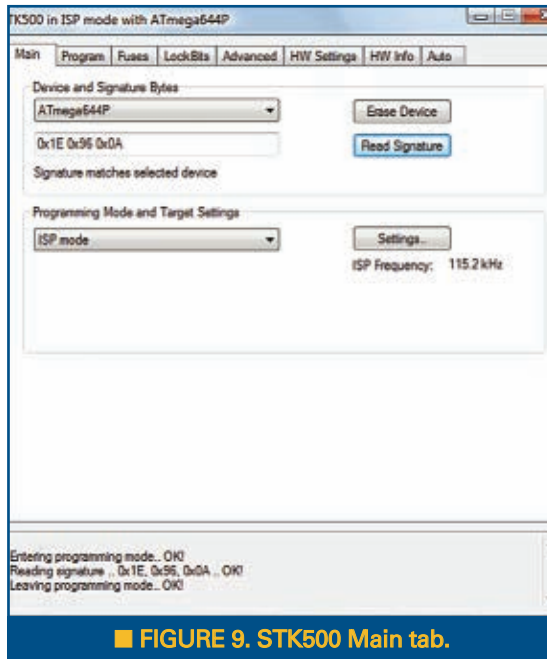
in **Figure 8** on which you click connect. [Note that in Workshop 22, we used the AVRDragon rather than the STK500 for the programmer, but the details shown here are the same.]

The ISP programmer window will open as shown in **Figure 9**, and in the Main tab you can click on the 'Read Signature' to verify that you are communicating with the ATmega644p. Next, click the Fuses Tab and change the settings to those shown in **Figure 10**. Then, click the Program button to set the fuses. We mentioned earlier that we'd set a fuse to help prevent writing when we are running out of power. We set the BODLEVEL fuse to "Brown-out detection at VCC=2.7V" as shown.

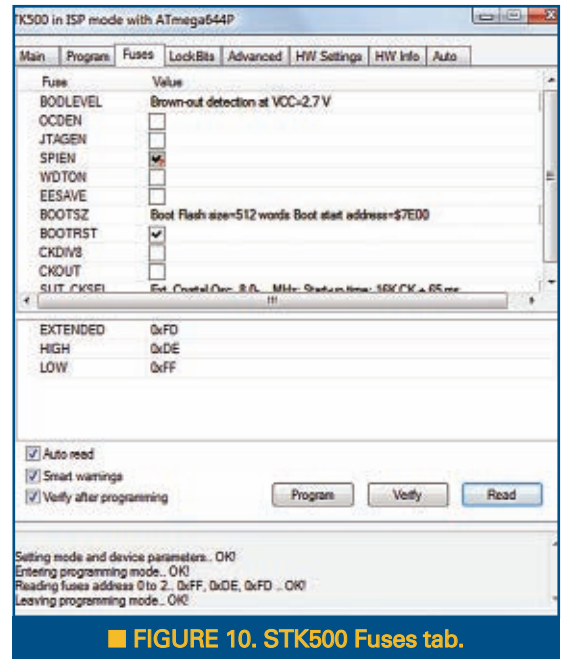
Finally, click the Program Tab shown in **Figure 11**, then you 'Browse' to select the directory containing the SmileyFlashTest.hex file. Click the 'Program' button and your bootloader should upload to your ATmega644.

Using SmileyFlashWriter

This is a simple program with three commands to read and write the sequence discussed above: 'r' to read the bytes; 'w' to write them in increasing order; and 'W' to write them to 0. When you first open the program, type in 'r' and you'll see 16 zeros; type 'w' then 'r' and you'll see the hex bytes 00 to 0F. Then, try 'W' and 'r' and you'll see 16 zeros. The output is shown in Bray's Terminal in **Figure 15**. But hey,



■ FIGURE 9. STK500 Main tab.



■ FIGURE 10. STK500 Fuses tab.

it does demonstrate that we are writing to Flash. Fun, huh!?

Reality Check – Did it REALLY write the data?

Yeah, we used 'r' to read the data we wrote to Flash,

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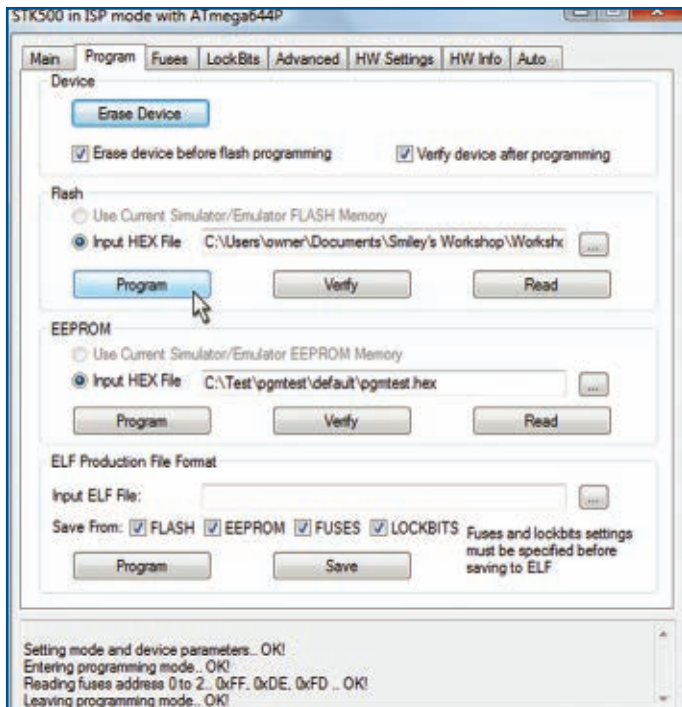
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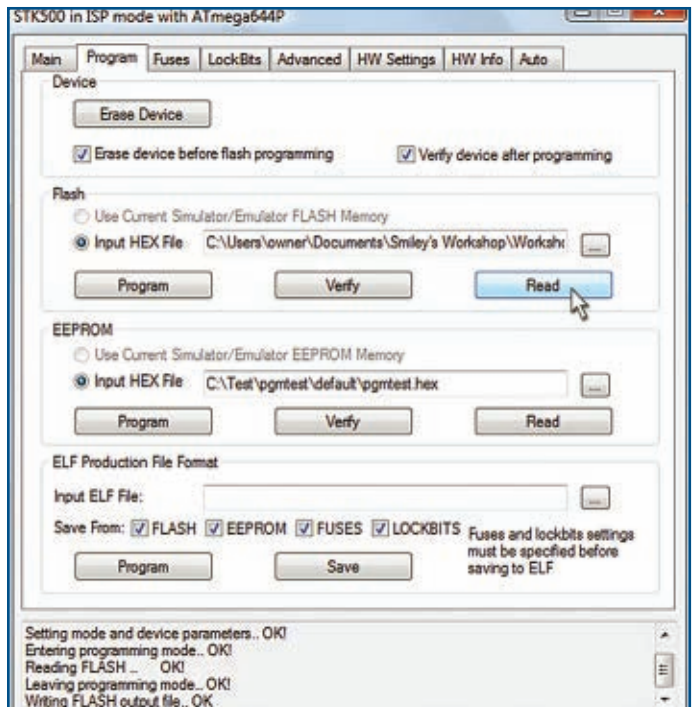
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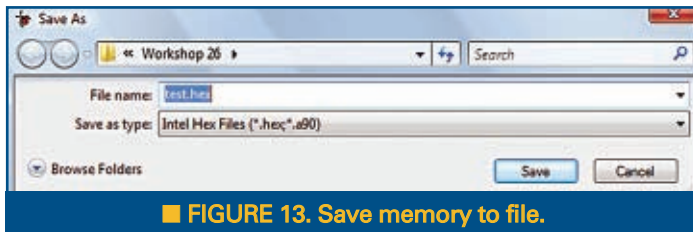
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■ FIGURE 11. Upload the bootloader.



■ FIGURE 12. Read memory.



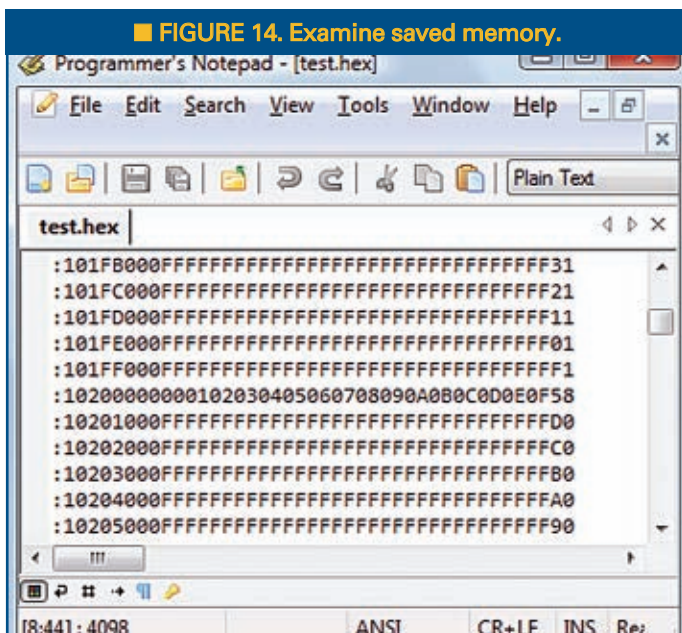
■ FIGURE 13. Save memory to file.

but we can add a second test to see if it really happened and read the whole Flash using AVRStudio. This is useful since it gives us a tool to inspect the entire Flash memory, which

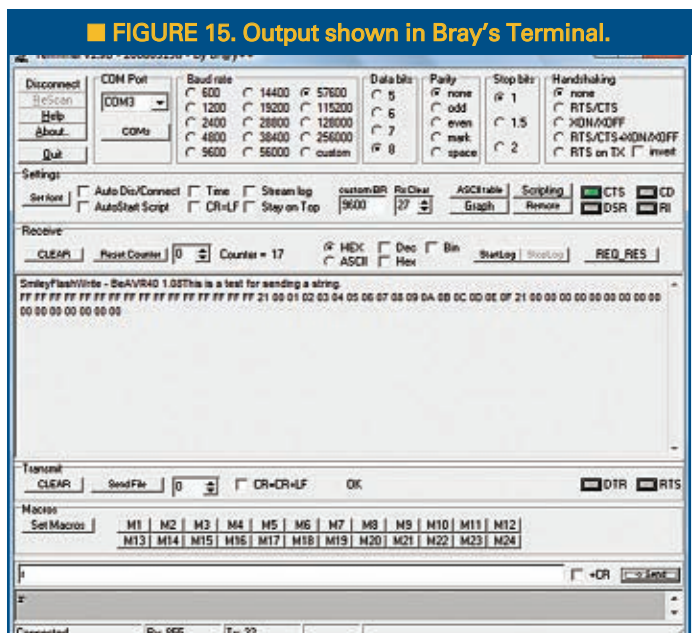
can come in handy in some debugging situations. To do this, we want to reopen the AVR Programmer dialog as shown in **Figure 12**, then click 'Read.' We are then asked to name the file that will hold the saved data, as shown in **Figure 13**.

Now we can open the test.hex file in Programmer's Notepad [part of WinAVR], scroll down to the memory location for 0x2000 as shown in **Figure 14**, then we can see our 16 bytes (nested in the Intel Hex formatted line).

Well, that was entirely too much for one Workshop. Next month, we will take what we've learned about memory and build a bootloader. **NV**



■ FIGURE 14. Examine saved memory.



■ FIGURE 15. Output shown in Bray's Terminal.

■ BY FRED EADY

GETTIN' JIGGY WITH THE VINCULUM-II HARDWARE DESIGN

Heat up your soldering iron. It's time to forge some solder, silicon, ceramics, plastic, metal, and fiberglass into an electronic instrument capable of transferring our ideas to a piece of silicon we know as the FTDI Vinculum-II. The first order of business is to pick up where we left off last month.

A MINOR DESIGN CHANGE

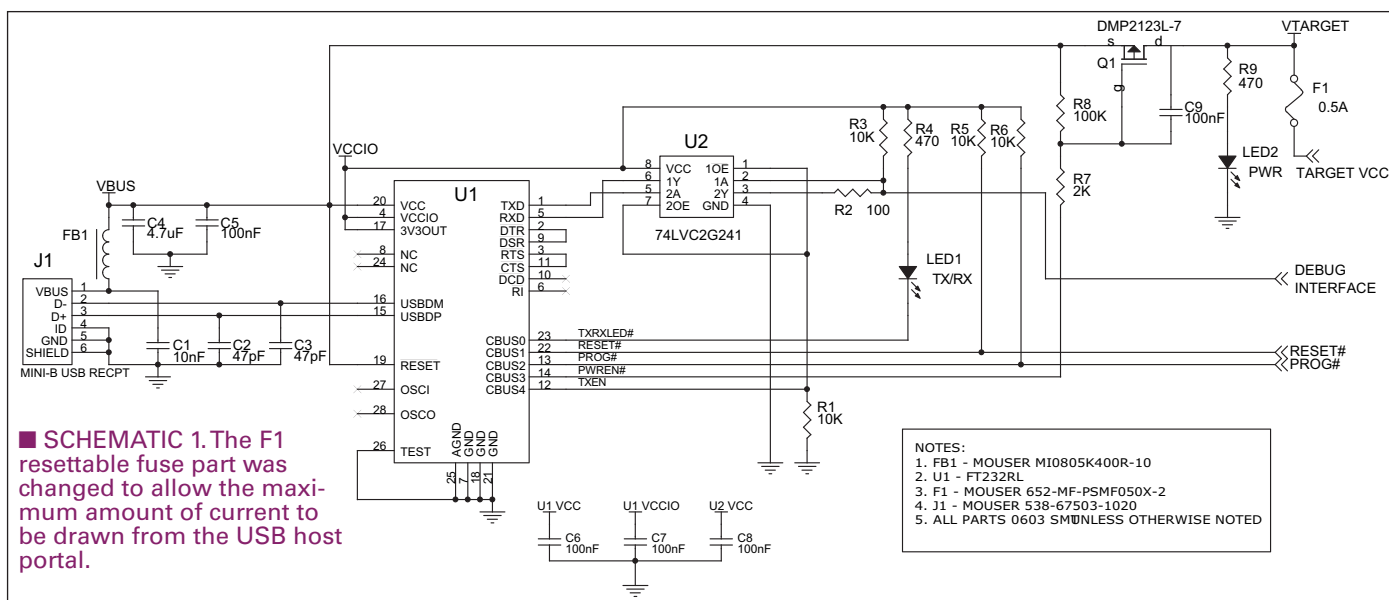
If you compare **Schematic 1** with last month's EDTP Vinculum-II debug module schematic, you'll see that the fuse component has been replaced. If you are ahead of the game and have already built up a version of the EDTP Vinculum-II debug module, no worries as the new fuse component has the same footprint as the fuse unit it replaces. The fuse that has been replaced was not rated to pass the maximum amount of current that a USB portal can provide. The PSMF020X is designed to hold at 200 mA and trip at 500 mA. The PSMF020X's amperage range is just fine for most low power circuitry. However, the replacement fuse — a PSMFX050X — holds at 500 mA and trips at 1,000 mA. Thus, if your external circuitry draws more than 200 mA and teeters at the maximum current drain of 500 mA, you won't be as likely to inadvertently trip the replacement resettable fuse. The host USB portal contains a similar over-current protection circuit and

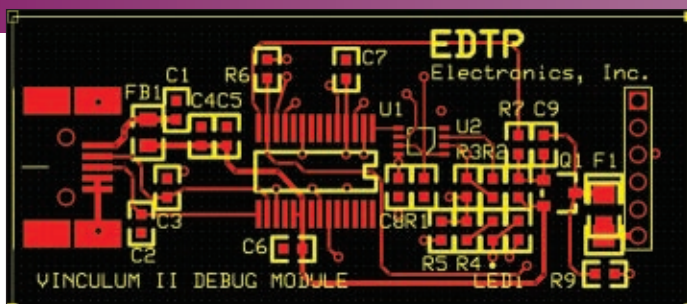
should not allow more than 500 mA of current flow for an extended period of time. However, my advice is to use your good judgment as to how not to invoke your circuit's magic smoke.

THE PRINTED CIRCUIT BOARD DESIGN

I remember the very first time I designed a circuit using 1/8 watt through-hole resistors. I recall worrying about how I was going to hand-mount those — at that time — tiny parts. Well, I did and the parts in my through-hole designs got progressively smaller. A similar evolution has taken place with our SMT designs. Our Vinculum II design here rests on a 1.975 x 0.85 piece of copper-laminated fiberglass and is full of 0603 SMT parts.

The debug module is constructed on a standard double-sided printed circuit board (PCB). From a purely trace layout point of view, the physical PCB design could have been simplified if we placed components on both sides of it. However, using the power of the PCB via our





■ **SCREENSHOT 1.** This screen capture is filtered to show only the component bearing pads and the supporting component-side traces.

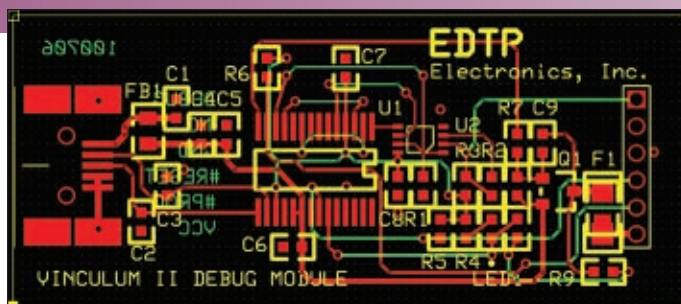
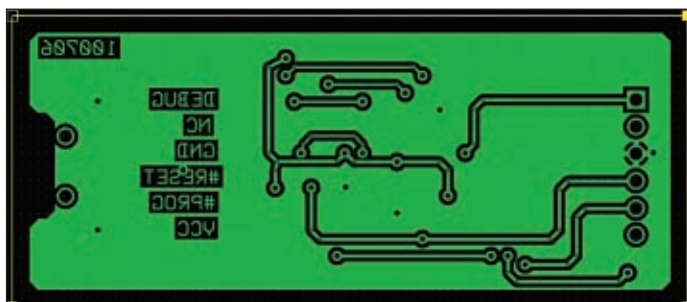
debug module PCB design here fits all of the electronic and mechanical components on a single side of the PCB.

The bottom layer copper, and top and bottom filled copper planes are filtered out in **Screenshot 1**. You can easily associate each of the electronic components with their graphical counterparts shown in **Schematic 1**. Components R8 and LED2 are not identified by silkscreen legends due to space restrictions. Our PCB is a product of the ExpressPCB generation process. So, you can identify each electronic component by simply clicking on it which will display the component's property window. Within this property window, you will find the size and value of the component, and if the component is not identified with a silkscreen legend component ID.

Between **Schematic 1** and the ExpressPCB layout, you can easily identify and correctly mount the electronic components and mechanical connectors that make up the debug module. Note the silkscreen dot that is associated with LED1. This dot represents the cathode of the LED. As you can see in **Screenshot 1**, the cathode of LED1 is tied to the cathode of LED2 with a copper trace. LED2 is located directly to the right of LED1 and is not identified with a silkscreen legend. LED2's current limiting resistor, R8, is mounted directly above LED2.

Screenshot 2 adds the bottom layer traces and legends under the component layer. Notice that some of the component layer vias don't have any bottom or top layer traces connected to them. These are pass-through vias that electrically connect the top and bottom ground planes. In some areas of the PCB, pockets are formed that isolate a grounded component lead from electrical ground. So, to complete the ground circuit, we simply place a via inside of the ground-less pocket which connects the upper and lower ground planes. The bottom

■ **SCREENSHOT 3.** The legend associates directly with the pins of the interface connector that is located at the far right of the board.



■ **SCREENSHOT 2.** This is a composite view of the top and bottom trace routing. No rocket science here.

side plane, traces, and legends are shown in **Screenshot 3**. ExpressPCB does not offer bottom-side silkscreen. So, the legends that associate with the debug interface pins are etched into the bottom side copper. Over the years doing hundreds of PCBs, I've discovered that using labels of any kind is always a good practice. The pass-through vias appear as holes in this screen capture because the vias are defined as solid pads instead of thermal pads. To see what a thermal pad looks like, look at pin 3 of the debug interface connector. The bottom side plane you see in **Screenshot 3** was constructed in the same way as the top side plane shown in **Screenshot 4**. Both the top and bottom planes are grounded, and you can see the thermal pads on some of the components that provide the electrical contact to ground. If you are from the planet Krypton, the debug module looks like **Screenshot 5** when you kick in your x-ray vision. The graphics that make up **Screenshot 5** come to life in **Photo 1**. Now that we have some programmer/ debugger hardware, the next logical step is to design and assemble a basic Vinculum-II embedded dual USB host controller circuit.

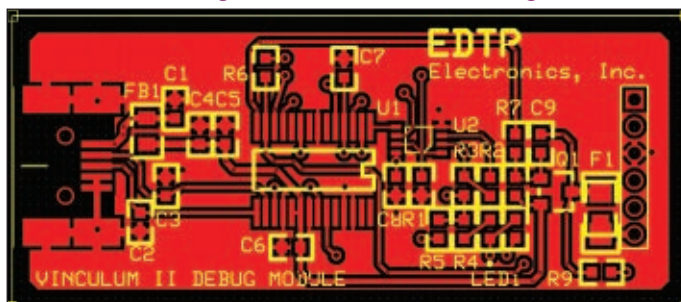
A BASIC HARDWARE DESIGN

Our host controller can act as both a host and a downstream device. So, we must design the Vinculum-II power supply circuitry with that in mind. To meet that requirement, our power supply design needs to be flexible as far as its inputs are concerned.

VINCULUM-II POWER SUPPLY DESIGN

We've successfully used the Microchip TC1262-3.3 LDO voltage regulator in a number of Design Cycle

■ **SCREENSHOT 4.** The use of ground planes greatly reduces the complexity of the printed circuit board by reducing the number of individual ground traces.



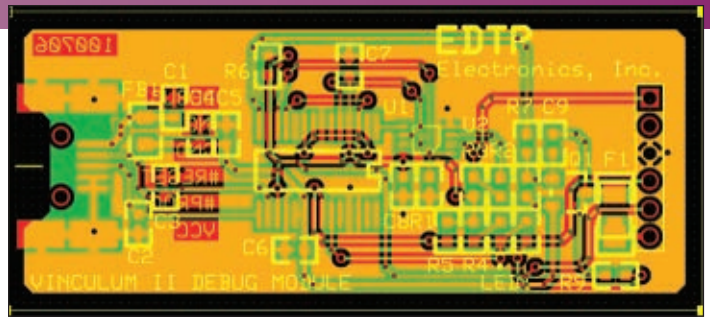
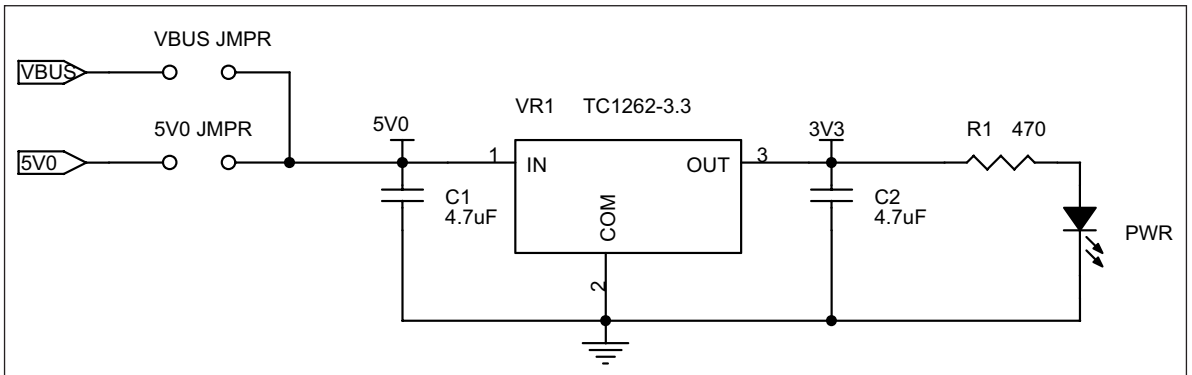
projects. The TC1262-3.3 LDO is capable of supplying loads up to 500 mA with a typical dropout voltage of 350 mV at full load. Designed for use in battery-powered applications, this voltage regulator can operate reliably with a pair of 1.0 μ F ceramic capacitors attached to its input and output pins. Recall my First Law of Embedded Computing which states, "Nothing is free." There is a "price" to pay for the TC1262-3.3 LDO voltage regulator's feature set. In this case, the price is cheap as it only costs us 80 μ A of power supply current to use it in our designs.

The TC1262-3.3 LDO input must be able to accept voltage from the USB portal and from an external source. If we decide to run the Vinculum-II in host mode, we'll need to supply the VBUS voltage at the host USB connector in the same manner your PC USB portals supply VBUS power to downstream devices. Our voltage regulator design is laid out in **Schematic 2**.

HOST INTERFACE DESIGN

If you study **Schematics 2** and **3**, you will conclude that any host USB interface has the ability to supply VBUS power to the TC1262-3.3 LDO. However, it is not politically correct to power a host USB portal externally. For instance, you wouldn't want to attempt to force VBUS power from an external downstream USB device into the USB portal of your thousand-dollar laptop. So, when operating as a host, the presence of the HOST JMPR x provides an electrical path to provide 5.0 volts to the downstream USB device. Since the host provides VBUS via its USB interface, 5.0 volts will probably be supplied externally. That means we need to provide an electrical path between the external 5.0 volt power supply and the input of the voltage regulator. This is easily accomplished by installing the 5V0 JMPR. Note that the VBUS JMPR and 5V0 JMPR are mutually exclusive as it pertains to having those jumpers installed. Our embedded dual USB host controller supports a pair of USB host portals which are identified as P0 and P1. The USB portals drawn up in **Schematic 3** are standard fare for most FTDI parts. ESD suppressors CR1, CR2, CR3, and CR4 are

■ **SCHEMATIC 2.** If you're a regular *Nuts & Volts* Design Cycle reader, there's no rocket science portrayed here either. The TC1262-3.3 LDO voltage regulator is a solid and proven electronic part shown here in a field tested design.



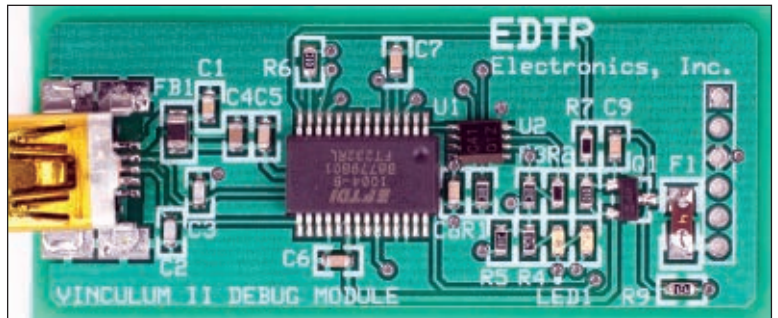
■ **SCREENSHOT 5.** Folks from the planet Krypton have an advantage over us Earthlings as they can check the top and bottom of their ExpressPCB layouts simultaneously.

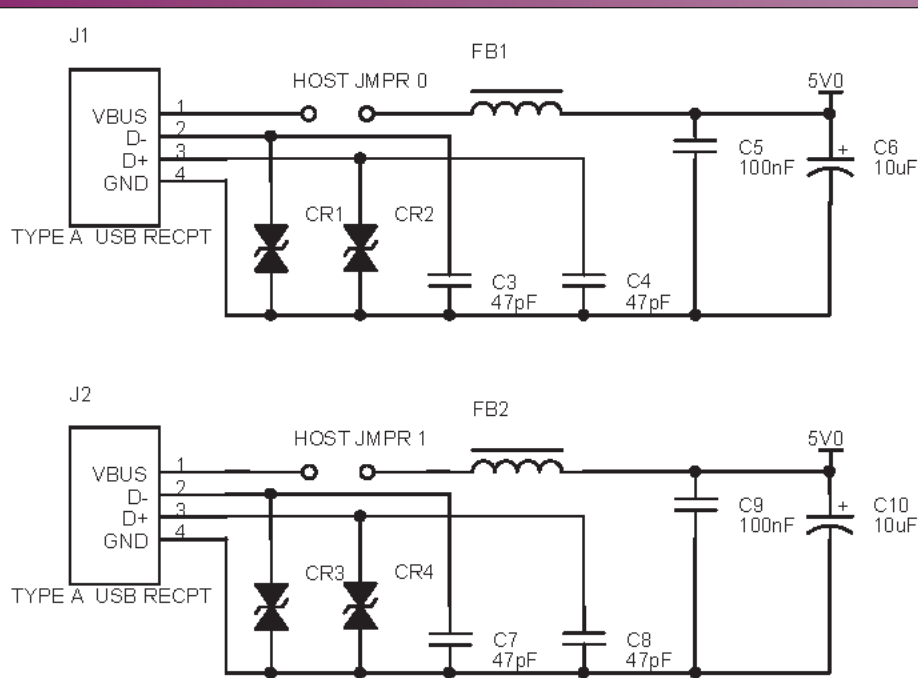
included to keep those nasty little sparks that tend to bridge electronic components and your fingertips from doing some unwanted soldering inside of the Vinculum-II IC. The ferrite beads FB1 and FB2 are in position to thwart EMI that may try to creep into the 5 volt supply.

VINCULUM-II CORE DESIGN

Like many of today's low voltage core microcontrollers, the Vinculum-II needs supporting electrical components for its internal voltage regulators. Pins 3 and 7 of the Vinculum-II IC grinning in **Photo 2** form the business end of the Vinculum-II's internal 1.8 volt power system. The 1.8V VCC PLL IN (pin 3) acts as the +1.8 volt supply to the internal clock multiplier. A 100 nF capacitor must be attached between this pin and ground. The output of the internal +1.8 volt regulator emanates from pin 7 of the Vinculum-II. **Schematic 3** shows a pair of filter capacitors hanging from the +1.8 volt output pin. Take another look at **Schematic 3** and you'll see a ferrite bead standing guard on the internal clock multiplier +1.8 volt input pin.

■ **PHOTO 1.** Rising from concept to reality, the EDTP Vinculum-II debug module.





NOTES:

1. CR1-CR4 - MOUSER 576-PGB1010603MR
2. FB1/FB2 - MOUSER 875-MI0805K400R-10
3. C6/C10 - MOUSER 74-TR3A106K6R3C1500

■ **SCHEMATIC 3.** This circuit is primarily used in host mode applications. For instance, a mass storage application would have this USB circuitry interface to a USB thumb drive.

Ferrite beads are popular components in this Vinculum-II design. The good news is that a single type of ferrite bead is used throughout the design. The whole +1.8 volt thing begins with the 3.3 volts entering at the Vinculum-II's pin 2 which happens to be the Vinculum-II's internal voltage regulator input. A basis for the Vinculum-II's logic voltage levels must be set to allow its I/O pins to interface

with external logic devices. That's where the Vinculum-II's VCCIO pins come in. The voltage applied to pins 21, 38, and 54 establish the logic level of the Vinculum-II's I/O subsystem. As you can see in **Schematic 4**, the Vinculum-II is a 3.3 volt device utilizing 3.3 volt logic levels. These days, 3.3 volt and 5.0 volt logic levels coexist more often than not. So, the Vinculum-II architects added 5.0 volt tolerance to all of the inputs.

If the debug module is attached to the Vinculum-II, there's no need for pull-up resistors on the active-low RESET and PROG lines as the pull-up resistors are mounted on the debug module PCB. If you're considering running the base system we've designed without the debug module attached, you'll want to pull up the Vinculum-II's RESET and PROG pins with a pair of 10K resistors just as we've done with R6 and R7.

Good power supply bypassing techniques are essential to properly operating microcontroller circuitry.

So, power supply bypass capacitors C16, C17, C18, and C19 need to be mounted as close as possible to the Vinculum-II's power pins that are directly connected to the source power supply's 3.3 volt output. The Vinculum-II's internal clocks and timers are driven from a clock signal derived from an external 12 MHz crystal. For this design, I've chosen a FOX resin-sealed crystal. The 12 MHz encapsulated crystal can be had from Mouser by specifying part number 559-FQ5032B-12.

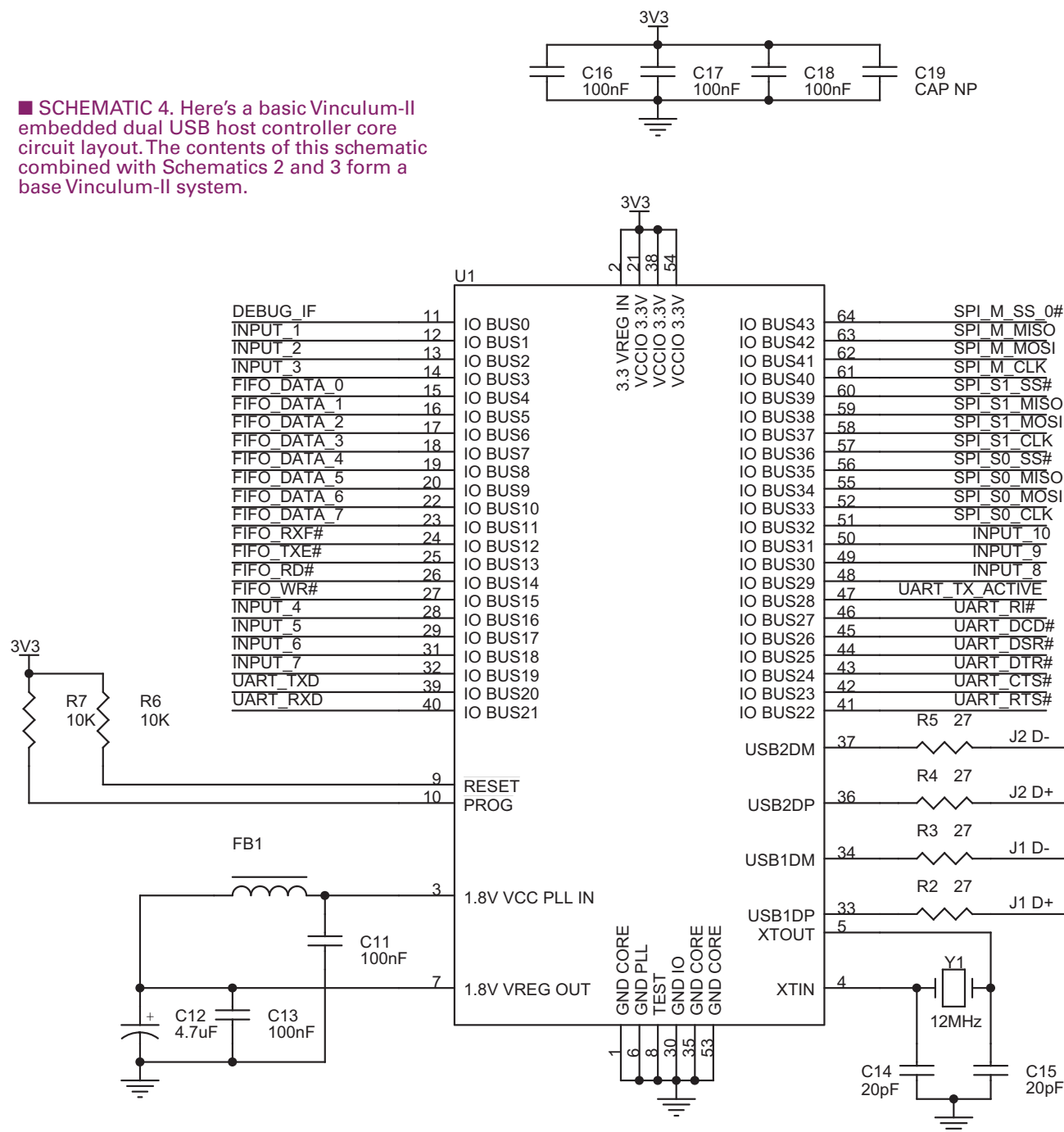
COLLECTING THE PARTS

Now that our design is committed to a set of schematics, we can begin the process of converting the graphics to silicon and fiberglass. Whenever possible, we'll use 0603 SMT components as they are more easily placed into tight trace-rich spaces. All of the electronic components that make up our Vinculum-II design can be had from **Mouser.com**. Rather than assemble a Vinculum-II unit that is locked into a specific application set, our hardware will take the shape of a portable module that can be plugged into an application-specific circuit. The pin assignments in **Schematic 4** represent the default I/O function set. If you had the opportunity to eyeball last month's Design Cycle, you know that we can configure these default I/O pin assignments to appear on alternate



■ **PHOTO 2.** It looks like a microcontroller. It acts like a microcontroller. It programs like a microcontroller. It is totally USB. This is the 64-pin version of the Vinculum-II. You can also get this IC in 32- and 48-pin variants.

■ **SCHEMATIC 4.** Here's a basic Vinculum-II embedded dual USB host controller core circuit layout. The contents of this schematic combined with Schematics 2 and 3 form a base Vinculum-II system.



pins. So, instead of identifying each pin on the PCB with its default value, we will label each of the Vinculum-II's I/O pins according to its IO BUS number. The USB connectors I've had the pleasure of meeting don't cotton to the 0.1 inch pitch holes found on common perfboards and solderless breadboards. So, we'll put all of the USB and similarly "difficult" to mount connectors on the Vinculum-II PCB module. Basically, any component that won't naturally fit into a 0.1 inch hole pattern will be mounted on the PCB.

Multi-microfarad SMT ceramic capacitors will be used whenever possible. The Vinculum-II reference designs I

have seen don't use SMT ceramics in the 1.8 volt regulator filter. Instead, the 4.7 μ F capacitor filter you see in **Schematic 4** is a tantalum. However, you can be sure I'll experiment with a similarly valued ceramic capacitor in place of the tantalum. I'll also attempt to replace the 10 μ F tantalums in **Schematic 3** with their SMT ceramic counterparts. To accommodate my (and your) experimentation, the PCB design will include dual pad shapes at the tantalum part locations that can accept both tantalum and ceramic footprints. My gut feeling is that the ceramic capacitors will work just fine. As far as our Vinculum-II design is concerned, the advantages of using

Vinculum VNC2

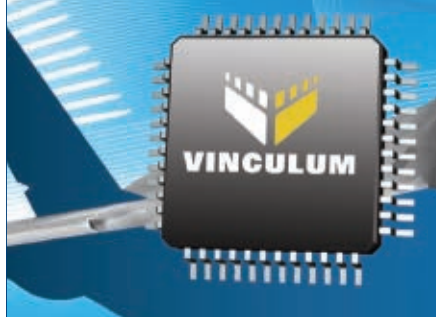
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ceramic over tantalum capacitors are lower cost and conservation of PCB space.

DESIGN CHECKPOINT

As our Vinculum-II base hardware is yet to become a physical entity, at this juncture of our design process I can only smoke-test the debug module. So, as soon as the solder cooled, I plugged it into a PC USB portal and observed a very brief blink of the debugger's LED indicators followed by absolutely nothing. In our case, that's a good thing. The magic smoke contained within the electronic components was not released. The PC USB portal also retained its magic smoke and the computer suffered no electrical damage due to its connection to the debug module.

The FT232RL's GPIO pins can be configured with commands embedded within the incoming USB data stream. However, before the FT232RL's GPIO can be configured for use by the Vinculum-II IDE, the debug module and the target circuitry must be powered up. Once all of the hardware is under power, the Vinculum-II IDE reads the EEPROM of the debug module's FT232RL which contains the FT232RL's USB description and serial number strings. The Vinculum-II IDE also needs the Vinculum-II IC's chip type information. This data harvesting arrangement allows multiple debugging devices to be attached. The Vinculum-II information and FT232RL EEPROM data are used by the Vinculum-II IDE to determine what types of debugger/programmers are attached and which Vinculum-II IC is targeted by the attached debugger/programmer device or devices. The desired debugging device can then be selected via the Vinculum-II IDE. That explains why the IDE returns a "No Debugger Available" message and the debug module hardware seems dead when no target Vinculum-II circuitry is present. During this process, the Vinculum-II IDE does not attempt to program

the FT232RL's EEPROM.

ONWARD

Keep that soldering iron handy. We'll have more hardware to assemble when we reconvene. In the meantime, I'll get the Vinculum-II core PCB laid out and manufactured. After we assemble the Vinculum-II core, we'll mate it up with the debug module. While that soldering iron is cooling off, we'll whip up some Vinculum-II application code.

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■ BY L. PAUL VERHAGE

THE CANON HACKER DEVELOPMENT KIT

The Canon Hacker Development Kit is a “bootable camera operating system” with a simple scripting language that significantly increases the power and flexibility of Canon “point and shoot” digital cameras. A simple script can give a Canon camera its own intervalometer while more complex programs allow a camera to vary settings like zoom, f-stop, shutter speed, and exposure time while it’s taking pictures. A big thanks goes to Mark Conner and the folks on the GPSL Yahoo! groups for making me aware of this fantastic camera system.

Canon Hacker Development Kit



When I began this near space business in 1995, if I wanted to take pictures during a mission, I’d have to perform a little surgery to the camera to allow the flight computer to control its shutter. Essentially, I’d bypass the electric switch of the shutter and re-route it to a relay controlled by the flight computer. Modifying an electrically triggered camera this way entailed a small amount of risk, as there was always the possibility that it could result in a damaged or inoperable camera. This was especially true when it was a tiny switch soldered to a plastic ribbon.

THE CANON HACKER DEVELOPMENT KIT (CHDK)

Today, embedded microcontrollers and firmware control the operation of cameras. No longer do buttons and dials mechanically adjust mechanisms within a camera. Now, buttons just apply electrical signals to the microcontroller to change menus and adjust settings. When the shutter button is pushed, firmware determines the proper exposure time based on inputted data and lighting conditions. Embedded systems let point and shoot cameras take a lot of the guess work out of taking pictures.

CHDK is software that controls a point and shoot camera the same way you can control a more expensive digital single lens reflex (DSLR) camera. CHDK — which is designed only for Canon cameras — uses scripts written in

a simple programming language called uBASIC. The commands grant control over features of the camera, making it possible to do things such as:

- Work with images in RAW format (RAW format is usually only available in DSLRs).
- Change shutter speeds to longer or shorter values than are normally available.
- Change aperture settings.
- Change zoom settings.
- Take bursts of photographs while changing exposure and aperture settings.
- Change focus settings.
- Use high speed flash.
- Take pictures when motion is detected (this includes detecting lightning flashes).
- Use the camera’s USB cable as a remote shutter.
- Create new menus and screens for the camera’s LCD.
- Add new video features to a camera.
- Change the camera’s file size limits.
- Use file utilities on the camera’s SD card.
- Create games for use on a camera.

Software commands for the camera are saved in scripts on the camera’s SD card. The camera then boots off the card and runs the script you select. Best of all, scripts don’t change the camera’s firmware. After running a script, you can escape out of it or remove the SD card from the camera. The camera will continue to function like

any other camera off the shelf. It's highly unlikely that using CHDK can physically harm your Canon — except maybe if you're driving the lens focus mechanism while the camera is against a wall — so CHDK is a safe way to modify the functioning of a camera.

Many volunteers have developed and expanded CHDK over time. As new camera models become available, volunteers port new versions of CHDK for these cameras. To download the Canon Hacker Development Kit, go to its Wiki site at <http://chdk.wikia.com/wiki/CHDK>.

MY EXPERIENCE WITH CHDK

I found a reasonably priced Canon A550 on the Internet to use to learn about CHDK. Before actually purchasing the camera, I made sure there was a CHDK version for the PowerShot A550. The CHDK Wiki site comes in handy here, as it lists the currently supported camera models. After receiving the camera and a new 2 GB SD card, I followed these steps to verify my A550 had the correct firmware version for the copy of CHDK I downloaded.

- Inserted the SD card into a PC, clicked My Computer, and formatted the SD card.
- Started Notepad, but before typing anything, named and saved the blank file by clicking File, then Save As.
- In the Save As window, selected All Files.
- Gave the file the name ver.req and saved it in the root of the formatted SD card.
- Repeated this a second time with a file name of vers.req.

Note: *ver.req means version required. Some Canon cameras require a file named ver.req to report the firmware version and others require a file named vers.req. Just to be certain I had the correct file name, I saved both files on the SD card.*

- Removed the SD card from the PC and loaded it into the Canon A550.
- Started the camera in play mode.

Note: *Check your camera's directions, but my A550 uses the upper left button to toggle between play and photograph.*

- Held the FUNC.SET button and then pressed the DISP button.
- Observed the LCD screen as it displayed the firmware version and a date (my camera's details were GM1.00C 4 Dec 2006).
- Checked the CHDK documentation for

■ These are the buttons I use on my Canon PowerShot A550. Other Canons use similar buttons, but their locations may vary.



■ CHDK splash screen.

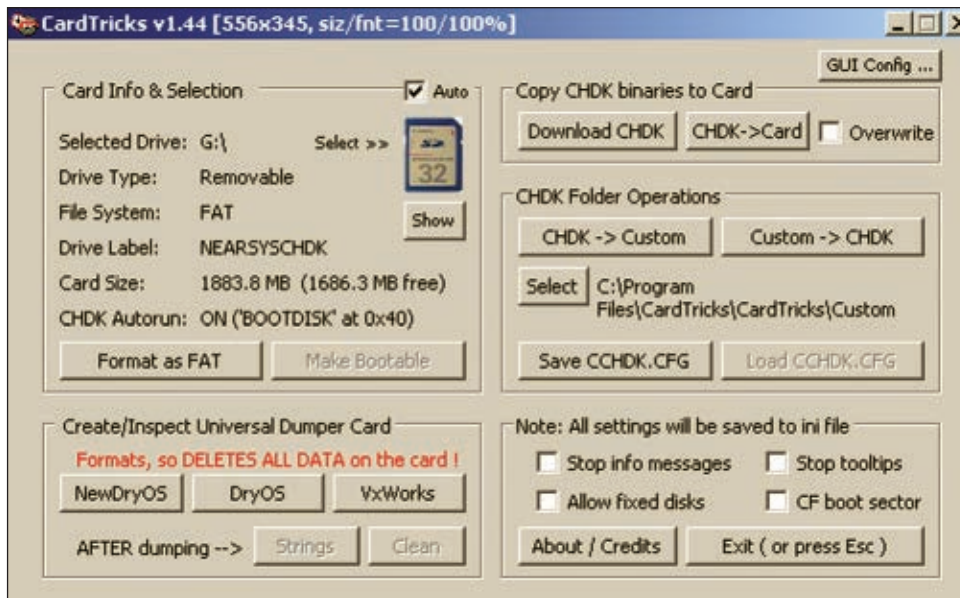
the version I downloaded and found it was designed for a Canon PowerShot A550 with version 1.00C firmware.

So far, so good. My new camera read the file I saved on its SD card and gave me the version and date of its firmware in response. The CHDK Wiki actually suggests following this procedure *before* you purchase a new Canon. So, prepare an SD card as I described above and take it to the camera store. There, get permission to load the SD card in a camera and check the camera's firmware version before you purchase it.

Now it was time to prepare the SD card for installation of CHDK. You can install all the files yourself or use an application called CardTricks which is what I did. Back at the CHDK Wiki, I found the CardTricks program and the CHDK version for my Canon A550. I installed CardTricks on my PC and unzipped the files in a directory on the hard drive where I would remember where I put them.

To install CHDK, the SD card must be removed from the camera and inserted into the PC's card reader. Note, you cannot install CHDK by leaving the SD card in the camera and attaching the camera to the PC with its USB cable. You must remove the SD card and install CHDK directly through the PC. The USB cable lets you view and





■ The screen for the CardTricks application. Use CardTricks if you don't want to install all the CHDK files manually.

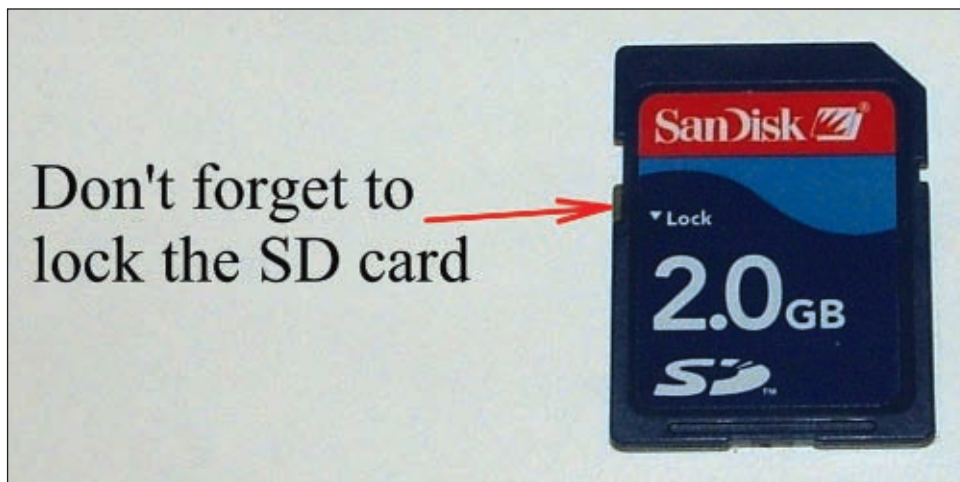
followed these steps:

- Clicked the CardTricks icon.
- At the **Browse for Folder** window, selected the SD card.

***Note:** It was important I selected the correct drive letter for the SD card. What I was about to do to the SD card would ruin the files on any other drive.*

- Clicked the **Format as FAT** button to prepare the SD card (and add the ver.req file again).
- Clicked the **Make Bootable** button (this is required for the camera to boot off the SD card and run the CHDK program).
- Clicked the **CHDK -> Card** button (this copied all the CHDK files, saving me the trouble of copying them manually).

Now I was done and CHDK was installed on the camera's SD card. I removed the card and slid its Lock button to the locked position. You might ask, lock an SD card you want to save images on? Yep, this makes the SD card bootable and loads CHDK



copy files on the card, but not place or edit files on the card.

After installing CardTricks, unzipping the CHDK files, and inserting the SD card into my PC's card reader, I

automatically on power-up. When running CHDK, the camera will override the lock button and write image files to the locked SD card.

■ After the CHDK splash screen appears, press the ALT button. The ALT message is displayed on the LCD for confirmation.



■ Next, press the FUNCT. SET button to bring up the CHDK menu.





■ While “Load script from file...” is highlighted in the CHDK menu, press the FUNCT. SET button a second time to display a list of scripts saved on the SD card.

At this point, the SD card is ready to be put back into the camera. When the camera is started with a locked SD card installed with CHDK, a splash screen briefly displays. You can ignore CHDK if you wish and operate the camera manually; you are not required to use the CHDK scripts if you don't want to. However, I was ready to edit and test my first scripts. There are dozens of scripts available online, so you don't have to create your first script from scratch. I recommend using an existing script and editing it for your purposes.

CHDK SCRIPTS

Recall that uBASIC commands are written into the scripts that set camera features and automate functions. Remember, scripts make it possible to trigger a sequence of photographs with varying parameters.

You write scripts in Notepad or any other editor that



■ Scroll up and down the list until the desired script is highlighted. Then, press the start button. The camera lens will open and extend, and the script waits for the shutter button to be pressed. Pressing the shutter button then activates the script. Once a script is started, the LCD screen displays *** STARTED *** at the bottom. To stop the script, press the shutter button a second time. You can shut a camera off at any time by pressing the power button.

does not add special characters to the file or document. You save completed scripts as .BAS files by clicking **Save As**, selecting All files in the **Save As Type** window, and typing the full name of the script in the **File Name** window. Be sure to save the file on the SD card under SD Card:/CHDK/SCRIPTS.

That's a beginning for using CHDK. Next time, I'll discuss some of the uBASIC commands and the USB remote I created for my A550. I'll also show you how I modified a BalloonSat Mini flight computer to use a USB to trigger my camera on near space missions.

Onwards and Upwards,
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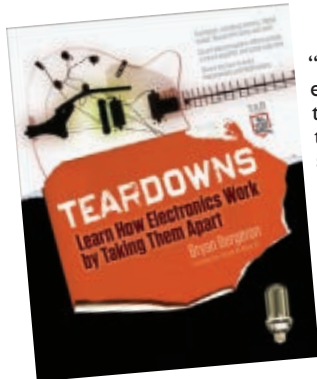


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ELECTRONICS

TEARDOWNS

Learn How Electronics Work by Taking Them Apart
by Bryan Bergeron



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From the Foreword by Forrest M. Mims III

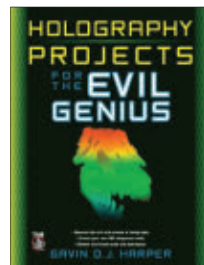
Amp up your knowledge of electronics by deconstructing common devices and analyzing the revealed components and circuitry. *Teardowns: Learn How Electronics Work by Taking Them Apart* contains 14 projects that expose the inner

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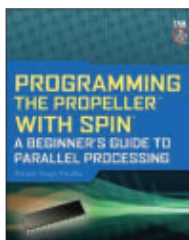
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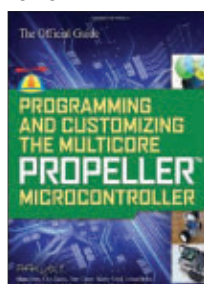
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Programming and Customizing the
Multicore Propeller Microcontroller
by Parallax

Written by a team of Propeller experts, this authoritative guide shows you how to realize your design concepts by taking full advantage of the multicore Propeller microcontroller's unique architecture. The book begins with a review of the Propeller hardware, software, and Spin language so you can get started right away and is filled with a wide variety of step-by-step, hands-on projects.

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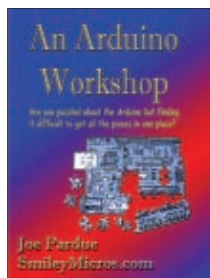
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An Arduino Workshop
by Joe Pardue

The Arduino — designed for the novice — has become so popular that there is now an embarrassment of riches when it comes to the amount of information and hardware available. So much stuff is out there that some folks have trouble puzzle piecing out what they need to just get started. The author is known for his breezy writing style and lucid illustrations that help folks understand complex technical topics.

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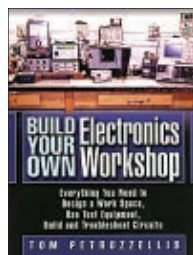


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Electronics Workshop
by Thomas Petruzzellis

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This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components, to putting the shop into action — building, testing, and troubleshooting systems. The best part is, this book will save you money.

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Programming 16-Bit PIC
Microcontrollers in C
by Lucio Di Jasio

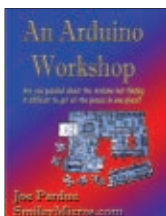
This book teaches readers everything they need to know about these chips: how to program them, how to test them, and how to debug them in order to take full advantage of the capabilities of the new PIC24 microcontroller architecture. Author Lucio Di Jasio offers unique insight into this revolutionary technology, guiding the reader step-by-step from 16-bit architecture basics through even the most sophisticated programming scenarios.

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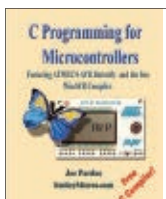
From the
Smiley Workshop
An Arduino
Workshop
by Joe Pardue



The book *An Arduino Workshop* and the associated hardware projects kit bring all the pieces of the puzzle together in one place. With this, you will learn to: blink eight LEDs (Cylon Eyes); read a pushbutton and 8-bit DIP switch; sense voltage, light, and temperature; make music on a piezo element; sense edges and gray levels; optically isolate voltages; fade an LED with PWM; control motor speed; and more!

An Arduino Workshop Combo

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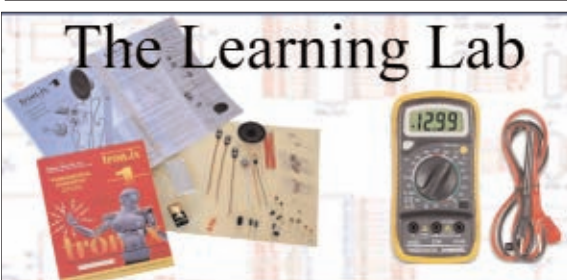
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PROJECTS

Bike Blinker Plus Kit

NEW!



As seen on the August 2010 cover

From the article "Bike Blinker Plus,"
 by DAVID G. BODNAR

The kit is a unique helmet-mounted LED lighting system that not only alerts drivers that you are on the road, but provides the user and fellow cyclists with some useful information as you ride. Includes construction plans and helpful SMT soldering hints.

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Wireless Taillight Kit



As seen on the cover of the July 2010 issue of Nuts & Volts.

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Includes an article reprint.

Subscriber's Price **\$139.95**

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A partial kit is also available.

16-Bit Micro Experimenter Board



Ready to move on from 8-bit to 16-bit microcontrollers? Well, you're in luck! In the December 2009 Nuts & Volts issue, you're introduced to

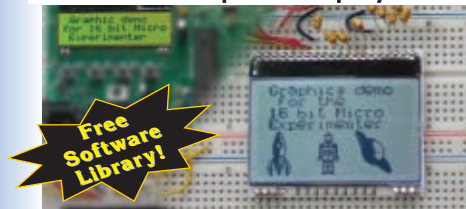
"the 16-Bit Micro Experimenter."

The kit comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications will be added in upcoming months.

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128x64 Graphics Display Kit



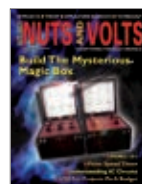
New application for the 16-Bit Micro Experimenter

LCD displays ... they have been around for quite some time, but what if you could have both characters as well as graphic displays at the same time? With this kit, we will show you how easy and inexpensive this technology can be using the 16-Bit Micro Experimenter.

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Magic Box Kit



As seen on the April 2007 cover

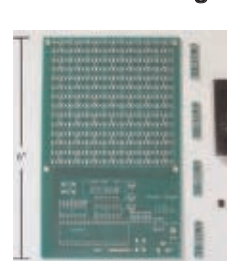
This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

Includes an article reprint.

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Indoor Shooting Range PCB & Programmed Chips



As seen on the May 2010 cover



Build your own indoor shooting range! With a little part-customizing for your own weapon and components from your favorite parts house, you'll be firing photon bullets in no time. We have the printed circuit boards and the two programmed chips necessary for this great project available for your convenience.

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rCube Talking Alarm Clock Kit



As seen on the May 2009 cover



Available in blue, black, red, and green. All components are pre-cut and pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

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October 2006

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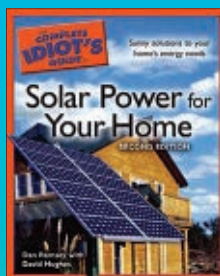
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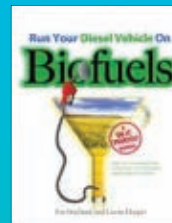
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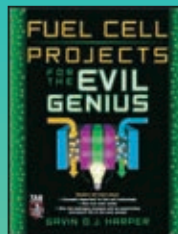


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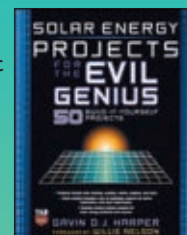
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The CXT and CXR come in compact shielded housings, measuring 33 mm x 23 mm x 9 mm and 46 mm x 23 mm x 9 mm, respectively, with pins for PCB mounting. The modules have an operating temperature range of -20°C to +55°C and conform fully with EN 300 220-3 and EN 301 489-3 standards. Class one (to EN300-220-v2.3.1) receiver versions are also available.

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For more information, contact:
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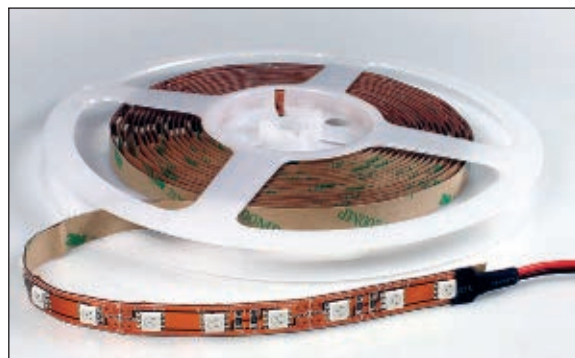
Thanks to the inclusion of easy to use, single-function controllers/actuators, the CXT and CXR modules are suited to tasks that just call for a simple on/off control function (such as flood light control, machine override shutdown, etc.), without the need for any additional external circuitry (such as a microprocessor or dedicated encoder/decoder IC). This keeps the size, bill of materials cost, and software overhead associated with system designs that employ these modules to a minimum.

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The CXR receiver has a better than -118 dBm usable calling sensitivity while drawing only 20 mA from a 3.1V-15V rail. The matching CXT transmitter can be offered in 10 mW (35 mA from 3.1V-15V) or 100 mW (95 mA from 4.1V-15V) versions, depending on specific band regulations.

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>>> QUESTIONS

Milwaukee Screwdriver Battery Chargers

I am a soon to be retired industrial electrician. At work, we use many cordless screwdrivers, mostly Milwaukee and Dewalt. I have several no longer functional 48-59-0180 chargers. It looks like a relatively simple circuit. I haven't indentified an in-line chip. Can anyone help with schematics and components?

Replacement 48-59-180s are no longer available. Replacement 48-59-300s are available, but at half the cost of an entire screwdriver kit.

**#9101 Marv Steinhagen
Davenport, IA**

Automatic Door Locks

I have a 1984 Cadillac that the automatic door locks do not work.

The doors lock from a 12 volt positive pulse from the gear selector switch as it crosses the reverse position. This also sends a signal to the back-up lights which work fine.

Does anyone have a circuit to lock and unlock the doors?

**#9102 Frederick Rembetski
via email**

Electric Fence Monitoring

I currently operate a small 10 acre hobby goat farm, protected by a commercial 16 KV, high impedance, pulsed charge, electric fence spanning across rolling hills which are "not visible" from the house. Some of our goats are natural born escape artists — as determined to get out as coyotes and wildcat predators are to get in. I need a "smart circuit" that can detect whether: (1) animal fence contact was just a "one time" brief encounter (resulting in a successful rebuff); (2) there are multiple successive contacts within a set time period (as would be the case of a determined assailant); (3) there is a persistent reduced fence charge (from an entangled animal); or

(4) there is a total fence failure (due to a break in or total grounding of the system). Most importantly, the circuit must be able to identify which specific fence segment/zone the problem is located at for fast response. In the past, predators have patrolled just outside the fence eventually digging underneath it or jumping over it without contacting it, so some form of zone based non-contact perimeter sensing (possibly using air to wire capacitive couplings) would allow for early warning of a potential problem.

**#9103 Sebastian Sullivan
Makanda, IL**

Auto Audio Adjust

Every time I slow down to an intersection, I turn my stereo down slightly. I need a device to work with the brakes and final output; something with a delay and that slowly fades back up.

**#9104 Steve McKennon
via email**

HD Reception on FM Tuners

Is there an HD adapter that can be added to an existing FM stereo tuner, similar to the circuits we added years ago to receive stereo on a monaural tuner?

**#9105 John R. Seeley
Palm Bay, FL**

Power Supply for Optional DC or AC Input

How can I design a simple circuit that allows me to have the option of supplying 120 VAC or 15 VDC? Currently, I have two fixtures: one uses a LPS24+15V/1.7A 25W input and the other an external 15V supply.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted

Other than that, the fixtures are the same. I would like to have the option to plug in AC or to plug in a 15 VDC supply.

**#9106 Chuck Moskowitz
Ann Arbor, MI**

Keystone Jack Wiring

I need data/instructions on how to wire a keystone jack per specs 368A/B.

**#9107 Harry Campbell
Wind Gap, PA**

Voltage Dropping

I have two circuits in the same enclosure: one works on 12 VDC and the other on 9 VDC. I have a 12 VDC transformer for the one. I need a 9 VDC for the other. I tried with resistors to lower the voltage to 9 VDC with no success.

**#9108 Pete Theodoulou
Durham, NC**

>>> ANSWERS

[#4103 - April 2010] Cat RFID

We have four indoor/outdoor cats. My plan is to have each of them implanted with an RFID chip and to have a sensor over the cat door which will read them. The door is already wired to indicate "a cat has gone in" or "a cat has gone out." Now I want to know which cat, and also possibly have the cat door remain locked until a known cat approaches.

I purchased an RFID reader module from Parallax and although this worked okay with the tags supplied, there was no response from the RFID chip borrowed from our friendly vet.

Does anybody have a suggestion

by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

Always use common sense and good judgment!

Send all questions and answers by email to forum@nutsvolts.com
Check at www.nutsvolts.com for tips and info on submitting to the forum.

for (a) what type of RFID chip to use (there are more than one); and (b) where I can obtain a bare-bones scanner. I want to capture the tag ID using my own microprocessor when a cat is in range of the sensor.

RFID systems operate at different frequencies. For the system to work correctly, the frequency of the reader must be tuned to the frequency of the tag. The operation frequency of the system made by Parallax may be different from the frequency at which the animal tag identification operates. Even if both of them operate in the LF range, one may be operating at 125 kHz and the other one at 134 kHz. Moreover, even at the same operating frequency, the communications protocol that they use may be different, as these are not standard in the LF range.

You may want to experiment with other low-cost readers for hobbyists. A good source is here: www.trossenrobotics.com/c/usb-serial-rfid-readers-tags-kits.aspx.

The popular website **Instructables.com** has several projects related to RFID systems (search for RFID). From all of them, you may be interested in this one: www.instructables.com/id/RFID_Reader_Detector_and_Tilt_Sensitive_RFID_Tag/.

Finally, there is a website that not only describes in detail the chips used by veterinarians, but it also gives details to construct a reader. This may be the closest to what you are looking for. This website is www.maxmicrochip.com/.

Albert Lozano
Shavertown, PA

[#4104 - April 2010] **Flame Rectification**

I would like to put together a flame sensor using flame rectification. I am familiar with how it works however, I need some ideas for the sensing electronics. The furnace I have uses a hot surface ignitor.

A simple flame rectification circuit can be easily made with an operational amplifier and a few discreet components. Choosing the popular '741 op-amp and one megohm resistor for feedback, I was able to breadboard a working circuit; the output from the amplifier drove a LED through a 330 ohm resistor. The input from the sensing rod (wire, in my case) went directly to the non-inverting (+) input of the op-amp; the inverting input (-) fed back to the output through the one meg resistor. Powered with five volts, it readily sensed the flame. In this case, I "grounded" the test flame with another wire. You can use this circuit to drive a relay or input to your favorite microcontroller. The very high input impedance of the op-amp allows for reliable low voltage operation.

Having said that, do not attempt to alter or modify the existing ignition and safety system in your gas furnace. The hot surface igniter on the domestic gas furnace works in conjunction with a very clever infrared flame detection system. It's designed for safety and has to meet the approval of various agencies before it can be sold to the public.

Carl, AE6NO
Lemon Grove, CA

[#4109 - April 2010] **PIC Micro and USB**

Long ago, I was competent programming in Microsoft QBasic. Now most/all articles use either assembly or C. Do any of the popular microcontrollers program in some version of Basic? I am not into a "C" level of retraining at age 67. Suggestions ... I'm looking for serious how-to articles — or worst case — books on using some microcontroller that includes interfaces to USB ports.

#1 I am an older techie like yourself tinkering with microcontrollers. Like you, I have used Basic for several years

and have not bothered to learn C or its derivatives. Lucky for us, there are several well established companies that build microcontrollers programmed in Basic. Parallax (www.parallax.com) sells the BASIC Stamp that is available in several versions, depending on features you need and how much you are willing to spend. The unit comes in a 24-pin DIP package that you will need to mount on a perf or breadboard to ease interfacing to. You can also purchase a complete development board with USB interface. Basic Micro (www.basicmicro.com) offers the Basic Atom which is also available in several versions. Both companies offer free downloads of an Integrated Development Environment (IDE) that allows editing, debugging, and compiling of programs on a PC or Mac. I have used both successfully in several projects. If your preference is the PIC line of microcontrollers from Microchip, microEngineering Labs (www.melabs.com) offers a complete line of Basic development systems for this product line. All of these companies have tutorials you can download or literature you can purchase to assist you in learning how to use their products. There is also a wealth of third-party information available and forums you can enter to assist you. P.S. I recently purchased an Arduino which is programmed with a language that is a subset of C in the hopes of disproving the theory that you can't teach an old dog new tricks!

Doug Foreman
via email

#2 I've been using the mikroBasic software from mikroElektronika (www.mikroe.com) for years now and am extremely satisfied. Good news is that you don't even have to buy the software if your projects can compile under 2K of code space. This is more than sufficient for all beginner level projects. I think they probably make most of their profit selling their

EasyPIC development board which is what I recommend for anyone just getting into PIC programming.

They also sell dozens of add-on boards that are designed to connect to their development board. These can be used to greatly reduce your development time. Then, if you later decide you want to build that component yourself instead of using an add-on board, they'll even provide you the schematic.

Their website also has free online books that are terrific tutorials for the beginner and a great reference for the rest of us.

The mikroBasic software itself comes with templates to demonstrate just about every feature on a PIC chip. So, you can quickly jump-start your new project by building up from their examples.

Alternatively, there is also PICBasic, but when I compared it to the features and cost of mikroBasic, there was, in my humble opinion, no contest.

Joe Kissell
Gardner, KS

#3 The Atmel AVR family of microprocessors has long been popular in professional, education, and hobbyist circles. As to Basic, arguably the very best structured Basic, very similar to Microsoft's Visual Basic 6, is the compiler called ZBasic (www.zbasic.net, and the user forum www.zbasic.net/forum.) This compiler targets the company's AVR chip based inexpensive microprocessor "stamp" products, with both byte-code and native code versions. Another Basic compiler for eight-bit microprocessors is from www.mcselec.com; it's an "old school" Basic which may bring back memories of spaghetti code! Finally, it's worth noting the Teensy micros from www.pjrc.com/teensy/ make a good target for most any compiler producing standard .hex downloadable files. The excellent and unrestricted WinAVR (GNY/GCC) with Atmel's free AVR Studio is very popular — due to the price: \$0. Of late, the dozens of Arduino variations have surged in use by those without a desire to muck

about in the details of the C language, at least as a starter.

Steve
San Diego, CA

[#41010 - April 2010] DC Motors

How does an interpole winding work in a DC motor?

#1 In a DC motor, as one commutator segment moves out from under a brush and another makes contact with a brush, the result is that sparking can occur at the commutator. To reduce the sparking, interpoles can be placed in the DC motor to help prevent brush sparking at the commutator. Interpoles are additional field windings placed on poles located midway between the field poles. The interpole coils are connected in series with the armature; therefore, the current they carry is proportional to the armature current. The interpole coils are wound so as to produce a magnetic field with a polarity opposite to the polarity of the magnetic field created by the armature current (thus, the magnetic field created by the interpoles is opposite to the magnetic field that is created by the armature). Interpoles aid the regular field windings in pulling the armature coils to and past the magnetic poles of the field windings.

Ralph J. Kurtz
Old Forge, PA

#2 Irving Gottlieb explains the operation of interpoles very nicely in his book *Electric Motors And Control Techniques*. A thorough answer is too long to print here, but to summarize: Interpoles are small poles (electromagnets) positioned half way between the main poles (permanent magnets) in a brushed DC motor. The interpoles are wired in series with the commutator and are "intended to combat the effects of self-induction and mutual induction in the armature inductors ... and improve commutation." If you're going to dive into motor theory, this book is worth the \$14 on Amazon.com.

Dan Danknick
Santa Ana, CA

[#5103 - May 2010] Load Controller, Micro Hydro

I built a 3,000W, 220V, micro hydro machine and installed it for a family of five living near a stream. I need a load controller to offset the extra power whenever something is turned off. When the real load goes down, the frequency and voltage go up. The design should monitor the frequency (50 Hz) and dump some load to resistors whenever the frequency starts going up, and dump less of that load when the frequency goes down. If there is a better idea please let me know. Is PWM a good option?

It appears that this is a stand-alone generator, not connected to any other power. Throwing a resistive load on to hold the output voltage and frequency in spec might be okay if you have a need for a lot of hot water or steam. Otherwise, it is wasteful.

My first choice would be to have a couple of control loops: The first loop is a speed stabilization loop to hold the speed relatively constant and give the desired 50Hz \pm a few Hz. This probably means controlling water flow/pressure to the turbine. The second loop involves controlling excitation of the generator to regulate voltage. Controlling excitation is very effective because exciter power is much lower than the output power of the generator. Stability and response time of the loops can be enhanced by sensing the load current on the generator and using that information to alter the loop signals before much speed or voltage change has actually occurred.

This may sound like a lot of trouble, but it saves water and will give better control than the shunt load responding to actual voltage or speed changes.

If you insist on the shunt load, the cheapest load is water itself. Use a controller to raise and lower a pair of iron plates in a big drum of water as a variable load. Use the stream water flowing through the drum to keep it cool.

Jon Wexler
Los Angeles, CA

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DC Accuracy	+/- 3%			
Timebase Range	4ns - 1h 38 Steps			2ns-1h, 39 Steps
Vertical adjustable	Yes			
Input protection	Diode clamping			
X-Y	Yes			
Autoset	30Hz-40MHz	30Hz-60MHz	30Hz-100MHz	30Hz-200MHz
EXT. input	Yes			
Trigger Mode	Auto / Normal / Single			
Trigger Slope	+/-			
Trigger Level Adj.	Yes			
Trigger Type	Rising edge / Falling Edge			
Trigger Source	Ch1 / Ch2 / EXT			
Pre/Post trigger	0-100%			
Buffer size	10K-32K per ch			10K-512KB per ch
Shot Bandwidth	DC to 40MHz	DC to 60MHz	DC to 100MHz	100MHz
Max Sample Rate	100MS/s	150MS/s	250MS/s	200MS/s / 250MS/s
Sampling Selection	Yes			
Waveform Display	port/line, waveform average, persistence, intensity			
Network	open / close			
Vertical Mode	Ch1, Ch2, Dual, Add			
Cursor Measurement	Yes			
Spectrum Analyzer				
Channels	2 Channels			
Math	FFT, addition, subtraction, multiplication, division.			
Bandwidth	40 MHz	60 MHz	100MHz	200 MHz
Cursor	Frequency, Voltage			
Data Samples	10K-32K/Ch			10K-1M/Ch



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19inch Rack Mount Switch-Mode Power Supply with 3 Output Modes



The BTI-150 is a high efficiency switching power supply. For use where multiple voltage continuous power output is needed. Ideal for use in Technical Product Research, Laboratory, Educational Institutions, Telecommunication Industry, etc.

The Rack Mount Design makes it easy to stack multiple power supplies for high use areas.

Output Voltage	Output Current	V/C Display	Resolution
0~15V	0~10A	Digital	0.1+/-2digit
0~30V	0~5A	Digital	0.1+/-2digit
0~60V	0~2.5A	Digital	0.1+/-2digit

Item #
BTI-150

\$189.00

www.circuitspecialists.com/BTI-150

Programmable DC Electronic Loads



These devices can be used with supplies up to 360VDC and 30A. It features a rotary selection switch and a numeric keypad used to input the maximum voltage, current and power settings. These electronic DC loads are perfect for use in laboratory environments and schools, or for testing DC power supplies or high-capacity batteries. It also features memory, and can also be connected to a PC, to implement remote control and supervision.

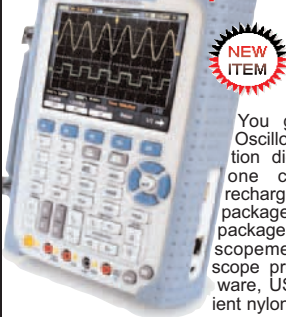
360V/150W (CSI3710A) \$349.00

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360V/300W (CSI3711A) \$499.00

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200MHz Hand Held Scopemeter with Oscilloscope & DMM Functions



Includes
1 Year USA
Warranty



You get both a 200 MHz Oscilloscope and a multi function digital multimeter, all in one convenient lightweight rechargeable battery powered package. This power packed package comes complete with scopemeter, test leads, two scope probes, charger, PC software, USB cable and a convenient nylon carrying case.

- 200MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 200MHz Bandwidth with 2 Channels
- 500MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item #
DSO1200

\$739.00

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)



Item #
DSO1060

\$529.00

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter w/Oscilloscope, DMM Functions & 25 MHz Arbitrary Waveform Generator

- All the features of the DSO1060 plus a 25 MHz Arbitrary Waveform Generator
- Waveforms can be saved in the following formats: jpg/bmp graphic file, MS excel/word file
- Can record and save 1000 waveforms
- DC to 25 MHz Arbitrary Waveform Generator



Item #
DSO-8060

\$659.00

www.circuitspecialists.com/DSO-8060

Programmable DC Power Supplies

- Up to 10 settings stored in memory
- Optional RS-232, USB, RS-485 adapters
- May be used in series or parallel modes with additional supplies.
- Low output ripple & noise
- LCD display with backlight
- High resolution at 1mV



Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W
Price	\$199.00	\$199.00	\$199.00

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BK4000
Thermostatically controlled desoldering station
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BK4050
HotAir System w/Vacuum IC handler & Mechanical Arm
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BK5000
Hot Air System w Soldering Iron & Mechanical Arm
\$119.00

BK6000
Premium All-In-One Repairing Solder System
\$229.00



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0-30V / 0-5A . DC Power Supply



The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 1/2 digit LED is used to display the voltage and current values.

www.circuitspecialists.com/csi530s

Item #
CSI530S

\$34.95

PropScope

2-Channel USB Oscilloscope

\$249.99



More info, downloads, & forums:
www.parallax.com/go/propscope

To order the **PropScope USB Oscilloscope** (#32220; \$249.99) visit www.parallax.com or call our Sales Department toll-free at 888-512-1024 (M-F, 7 a.m. - 5 p.m., PDT).

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Turn your PC into a full-featured oscilloscope with the PropScope (#32220; \$249.99). At 25 million 10-bit samples per second, use the PropScope to capture sine waves up to 5 MHz or square waves up to 12.5 MHz. Using the included 1x/10x probes, capture waveforms up to 200 volts peak-to-peak.

Also included, the DAC expansion card adds one analog and four digital triggers, a TV output, and an 8-bit function generator.

The design for the PropScope hardware, based on the eight-core Propeller microcontroller, is open source and fully documented. You can use the PropScope as is, or write your own firmware for countless off-label uses. Free PC-based software is available for Windows 2K/XP/Vista/7.

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